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BULLETIN 381

CONTRIBUTIONS
TO
ECONOMIC GEOLOGY
1908

PART II.—MINERAL FUELS

MARIUS R. CAMPBELL
GEOLOGIST IN CHARGE

WASHINGTON
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CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1908, PART II.

MINERAL FUELS.

Marius R. Campbell, *Geologist in Charge.*

INTRODUCTION.

By Marius R. Campbell.

During the year 1908 considerable progress was made by the United States Geological Survey in the study of the mineral fuels of the country. This included the examination of a number of coal and oil fields and also some work on the quality of the fuel and the best method of its utilization. Complete and detailed reports covering this work will be published as soon as the investigations of a particular field have been completed, or as soon as the problems of correlation, development, and utilization have been solved. In the meantime brief, preliminary statements have been prepared by the men engaged in the work, embracing most of the points of economic importance, and these have been assembled into the present volume, which is conformable with Bulletins 316 and 341. It is hoped that by this method of publication the public may receive at an early date the results of work done by this Survey, in order that the mineral resources of the country may be developed to the fullest extent compatible with legitimate demand and supply and a due regard to the conservation of these resources for future generations.

In the conduct of the field work on which these reports are based, two objects have been particularly prominent and have governed the character of the investigations: These are (1) the examination of the land for the purpose of classifying it as to its mineral or nonmineral character and, in the case of coal land, of determining its selling value; and (2) a general investigation of the scientific questions involved in any particular field and the determination of its commercial value and the best method of development.

The first or dominant factor was the determination of the character and the valuation of the public land. These determinations were made wholly for the use of the Government itself in disposing of its mineral land. The second or general investigation of the mineral resources of the country was made for the benefit of the public at large and the results of this work are embraced in the series of reports of which this volume is one. The order in which the fields are examined depends entirely on the needs of the Government in disposing of its land now on the market, but in general the more important fields in the public-land States have been examined first.

The work has been done under the general direction of the writer, who has been most ably assisted in the coal work by Cassius A. Fisher and all the men engaged in the work. It is impossible to enumerate the services performed by each man, but the success of the work has been due to the individual efforts of every member of the force and also to the hearty cooperative or team work without which it would have been impossible to carry on the work successfully. Although economic questions had to be given prominence, the writer wishes to congratulate each geologist on the amount of scientific data which have been accumulated and on the permanent value of the results and their bearing on the vexed question of the stratigraphy of the American Mesozoic and Tertiary rocks. The writer desires particularly to acknowledge his indebtedness to T. W. Stanton and F. H. Knowlton, who have so ably assisted in field and office in collecting and interpreting the fossils associated with the coal beds. This work has been invaluable, for without it the tangled problems of correlation and stratigraphy could not have been solved.

For forty years the age of the coal-bearing rocks of the Rocky Mountain States has been in dispute, and while it can not be claimed that the question is settled, still the Survey's systematic examination of the coal fields during the last three years, in connection with the classification of the lands, has gradually brought order out of chaos. Now the end seems to be nearly in sight, and it is confidently believed that a few years' work will completely solve this perplexing problem.

Necessarily, the classification and valuation of coal land presupposes a careful study of the coal itself to determine its physical and chemical properties and its heating value. In order to make such a study, samples have been collected from all the fields examined and either proximate or ultimate analyses made in accordance with regulations adopted by the American Chemical Society, the highest authority in this country. Sampling was done systematically and uniformly, and it is believed that the resulting analyses will be accepted as representative of the coals of the various fields. No other organization can carry on analytical chemical work so extensively and impartially, and the results should become the standards not only for buying and selling coal, but also for buying and selling coal land. The coal analyses already made by the United States Geological Survey number many thousand, and all of these are strictly comparable, except in a few cases, where weathered coal not typical of the bed or of the field was included in the sample. The analyses contained in this volume are published for the first time and they constitute an important addition to the mass of data already available regarding the composition and relative values of American coals.

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1908

COAL AND LIGNITE.

STRATIGRAPHY AND COAL BEDS OF THE INDIANA COAL FIELD.

By George H. Ashley.

INTRODUCTION.

In 1898 the State Survey of Indiana published a detailed report on the coal deposits of that State. In the years between 1898 and 1908 the coal industry of the State expanded greatly, several hundred new mines having been opened and literally thousands of drillings having been put down. The result of this work was to multiply greatly the available knowledge of the coal measures, as well as to show the existence of errors in the earlier report. In cooperation with the State the United States Geological Survey therefore made a reexamination of the area of development in 1908, the work being done by the writer with the assistance of E. F. Lines. The economic results will be published by the state geologist of Indiana, W. S. Blatchley, in his annual report for 1908. The scientific results will be published by the United States Geological Survey in a future report on the Eastern Interior coal field. The present paper is a brief preliminary general account of the stratigraphy and coal beds of the Indiana coal field.

THE INDIANA COAL FIELD.

The coal measures of Indiana lie in the southwestern part of the State, extending from Warren County on the north to Ohio River on the south, and eastward to a northwest-southeast line running from Warren County to Perry County. They cover practically all of sixteen counties and parts of nine additional counties. The Indiana field is part of the Illinois coal basin, or the Eastern Interior coal region. This region has a true basin shape, being deepest in the center in southeastern Illinois and rising to a rim on all sides. The Indiana field is a part of the eastern or northeastern rim, extending in the southwest corner of the State well into the center of the basin.

The coal measures have a total thickness of approximately 2,000 feet, of which about 1,300 feet occurs in Indiana. Of this 1,300 feet there are 600 feet of barren beds at the top, then a 500-foot interval which contains most of the workable coals, followed in descending order by 200 feet or more of rocks consisting mainly of sandstone. Recent work of David White indicates that the rocks of the upper 600 feet are of post-Allegheny age, those of the next 450 feet of Allegheny age, and the lower rocks of Pottsville age.

THE COAL BEDS.

OCCURRENCE.

Coal occurs at about thirty-four different horizons, of which about twenty-five have a fairly wide persistence. Of these beds one is workable nearly everywhere in the State where it outcrops and eight others are workable over large areas. Several of the smaller beds are workable locally. The average thickness of all the beds of the State is probably less than 2 feet, but the workable beds range from 3 to 8 feet. The most important bed in the field probably averages 5 feet within its outcrop, and over large areas averages 6 to 8 feet. Many of the other beds average 6 to 8 feet over several hundred square miles, but are thin or absent over adjacent areas. The maximum thickness measured was 10 feet 2 inches, though thicknesses of 11 to 15 feet are reported in "swamps."

A few individual coal beds can be traced the whole length of the Indiana coal field. In one case this tracing appears to be thoroughly reliable, and in several others it is apparently good, though the possibility of error must be admitted. Still other coal beds can be traced with only a fair degree of probability. On the other hand, beds which maintain a thickness of 6 or 8 feet over large areas thin out within the space of a few miles. In some beds such thinning out is against the edge of its basin, and though the horizon of the coal can be traced for miles no further indication of coal can be seen within the State. In other beds the coal is very regular over large areas and very irregular over similarly large areas beyond.

In general the upper beds are much more regular than the lower beds. In fact, the lowest beds occur in small, nearly detached basins, usually lying in a west of north and east of south direction and ranging from a few acres to several square miles in extent. In the center of one of these basins the coal may have a thickness of 5 feet, but between the basins on the ridges the thickness may decrease to as many inches. In these basins it is observed that where the coal has several benches the lowest benches thin out first in approaching the rise, so that the coal going over the divide into the next basin may represent only the upper part of the top bench. Of even more interest is the fact that at two horizons where the coal in the basins has a somewhat distinctive section, the same section is repeated from basin to basin over hundreds of square miles.

NAMES OF COAL BEDS.

Probably no coal field in the United States of equal size has been studied so completely and is now so well known as the Indiana field. One result of this study has been to show that as a rule thick or workable coals are found at only a few horizons. These horizons have been designated by Roman numerals from II to VII. Intermediate coals have been named by the addition of a small letter to the name of the first principal coal below. Thus the rider of coal V is coal Va; the still higher thin coal would be Vb, etc. Coal II is the lowest of the coals that David White has thought will prove to be of Allegheny age. To the underlying coals, thought by him to be of Pottsville age, local names have been given.

TYPE SECTION OF COAL BEDS.

One of the interesting things that have been emphasized by the results of recent drilling is the tendency of the coals in Indiana to reach their best development midway between the north and south boundaries of the field. Thus, several coals that are 6 to 8 feet thick in Sullivan, Greene, Clay, and Vigo counties are thin or lacking toward the north and south ends of the coal field and, with possibly one exception, all the workable coals of the State are workable in that area. The coals from coal III to coal VIII are best known in Sullivan and Greene counties, where each of the numbered beds ranges from 4 to 8 feet in thickness, with sections so distinctive that they can hardly be confused, and where about four hundred detailed sections, many of which show every foot of rock from coal III up to coal VIII, help to make the stratigraphy quite clear. Though considerable drilling has shown the relation of coal III to all the lower coals in Greene County, they are still better known in northeastern Vigo and northern Clay counties.

The portion of the following section from the Merom sandstone down to coal III is therefore taken in Sullivan County and the portion from coal III to the Lower Block coal in northeastern Vigo and northern Clay counties. The beds above the Merom sandstone are best exposed in Gibson County.

Type section of coal measures in Indiana.

	Thickness of beds.		Total thickness.
Gibson County.	*Feet.*		*Feet.*
Sandstone	6		
Shale, etc., with 6 inches local coal	20		
Sandstone, hard bedded	15		
Shale, partly covered	25		
Shale, sandy	8		
Shale, blue and argillaceous	8		
Limestone, soft and shaly to very hard	4		
		86	86
Aldrich coal		1	87
Shale, coaly	2		
Sandstone (sandstone of Mansfield Hills, etc.)	28		
Limestone, hard, gray, and fossiliferous	3		
Shale, black	3		
		36	123
Friendsville coal (0–4 feet)		2	125
Clay	1		
Sandstone, upper part massive (sandstone of Gordon Hills)	35		
Limestone or calcareous and fossiliferous sandstone	3		
Shale, black	5		
		44	169
Parker coal		1	170
Shale	16		
Sandstone	20		
Shale	10		
Sandstone, soft, and sometimes shaly	20		
Clay shale, bluish	5		
Sandstone, shaly	20		
Shale	25		
Top of Inglefield (Merom?) sandstone.			
Merom, Sullivan County.			
Sandstone, Merom	40		
"Productal" limestone, rich in fossils	3		
Shale, calcareous	1		
Shale, dark, bituminous	5		
		165	335
Coal VIIIb, rash		1	336
Fire clay	2		
Clay shale, dark	4		
Sandstone, coarse, hard	3		
Limestone, crinoidal, shelly	1		
		10	346
Place of coal VIIIa (?).			
Fire clay	½		
Sandstone, flaggy	3		
Shale, drab, with large iron nodules	10		
Shale, gray, with pyritous partings	25		
Sandstone, quarry	15		
Clay shale, hard, siliceous	4		
Clay shale, siliceous, with large iron nodules	7		
Clay shale, light-colored, with small round iron nodules	5		
		69½	415½
Coal VIII		3½	419
Sullivan and Greene counties in general.			
Clay	5		
Limestone	4		
Shale	8		
Sandstone	20		
Shale	20		
Sandstone, shaly	10		
		67	486
Coal VII (3–6 feet)		4	490
Clay	5		
Limestone	6		
Shale	3		
Sandstone	15		
Shale	10		
		39	529
Coal VI (5–9 feet)		6	535
Clay	5		
Coal	0–1		
Shale	5		
Sandstone	10		
Shale	23		
		44	579

Type section of coal measures in Indiana—Continued.

	Thickness of beds.		Total thickness.
Sullivan and Greene counties in general—Continued.	*Feet.*		*Feet.*
Coal Va		2	581
Clay	3		
Sandstone	10		
Shale	10		
Limestone	5		
Shale, black, sheety, with pyrite concretions	5		
		33	614
Coal V (0-11 feet)		7	621
Clay	4		
Limestone	2		
Shale	20		
Sandstone	25		
Shale	15		
Limestone	1		
Shale, black, sheety	2		
		69	690
Coal IVa		2	692
Clay	3		
Sandstone, shaly	30		
		33	725
Coal IV (4-6 feet)		5	730
Sandstone	30		
Shale	10		
Limestone	1		
Shale, black, sheety	2		
		43	773
Coal IIIa		1½	774½
Clay	3		
Shale	15		
		18	792½
Coal III (0-13 feet)		6½	799
Clay		6	805
Northeastern Vigo County and northern Clay County.			
Coal		1	806
Clay	1		
Shale	15		
		16	822
Coal		1½	823½
Clay	2		
Shale	2		
Sandstone	3		
Shale	10		
		17	840½
Coal		2	842½
Clay	3		
Shale	3		
Sandstone	8		
Shale	2		
Limestone	2		
Sandstone, shaly	10		
		28	870½
Coal		1	871½
Shale		10	881½
Coal II (0-4 feet)		2½	884
Clay	2		
Limestone	10		
Shale, black	3		
		15	899
Coal, Minshall (0-6 feet)		3	902
Clay	4		
Shale	7		
Sandstone	12		
Shale	7		
		30	932
Coal, upper block (0-5 feet)		3½	935½
Clay	4		
Shale	7		
Shale, sandy ("fake")	20		
		31	966½
Coal, lower block (0-5 feet)		3	969½
Clay	3		
Sandstone, Mansfield, replaced with shale at many places in the basin	70		
Shale	10		
		83	1,052½
Coal		1½	1,054
Clay	2		
Shale	10		
		12	1,066
Top of lower Carboniferous.			

The above section does not include the uppermost members in Gibson County nor the lowest members in the southeastern part of the field.

To give a better idea of the relation of the intervals between the different coal beds and the relative thickness of these beds in different parts of the coal field, the following table is inserted:

Intervals and thickness, in feet, of principal coals at a number of points over the Indiana coal field.

	Clinton district.	Northwestern Vigo County.	Northeastern Vigo County.	West Terre Haute.	Northern Sullivan County.	Central Sullivan County.	Southern Sullivan County.	Northern Knox County.	Washington, Daviess County.	Central Gibson County.	Northwestern Warrick County.	Central Warrick County.	Evansville.	Western Kentucky.
Coal VII	4½	5	......	5	4½	4	3	3	......	3½	3	2½	3	2-7
Space	55	50	......	50	40	30	55	40	......	15	10-½	10	15	3-40
Coal VI	0	0	......	0	5½	7	4½	5½	......	0-4½	3-0	2-0	0	0-9
Space	50	50	......	45	45	45	45	50	......	80	90	65	60	80
Coal Va	1½	1½	......	1	2½	3	2	3	2	1-0	1-0	0	0	0
Space	20	35	......	30	35	30	35	30	35	50	25	25	25	25
Coal V	6	5	......	5	6	6	5	7	7-4	6	4½	4-9	4	5
Space	60	60	......	63	65	85	85	75	90	90	50	45	45	......
Coal IVa	1	2	......	2	2	3	1½	1	1½	1-0	1	½	0	......
Space	30	35	......	45	45	25	30	25	35	20	45	45	40	......
Coal IV	4	4	......	5	3½	5	0	4	1	4	2½	2½	3	......
Space	45	40	30	30	45	30	35	....	40	......	......	40	......	......
Coal IIIa	2	2½	1½	2	1	1	1	....	1½	......	......	0	......	......
Space	40	40	25	25	20	25	25	....	40	......	......	35	......	......
Coal III	6	6½	7	6	7	6½	5	....	2	......	......	0-3	......	......
Space	......	......	110	......	......	......	......	....	......	......	......	......	......	......
Minshall coal	......	......	4	......	......	......	......	....	......	......	......	......	......	......
Space	......	......	30	......	......	......	......	....	......	......	......	......	......	......
Upper Block coal	......	......	3	......	......	......	......	....	......	......	......	......	......	......
Space	......	......	30	......	......	......	......	....	......	......	......	......	......	......
Lower Block coal	......	......	4	......	......	......	......	....	......	......	......	......	......	......

INDIVIDUAL COAL BEDS.

In discussing the coals it is convenient to take coal V as a base horizon. It is a thick coal with certain peculiarities of roof which render its recognition possible through the whole length of its outcrop in Indiana. It is at almost every point characterized by a roof of black sheety shale, the under surface of which contains pyrite concretions that, as a rule, project downward into the coal. In some mines these concretions are very abundant, the roof being almost botryoidal from their presence. In other mines they are only scattered, possibly one or two to a room, but they are absent in few of the mines. Some of them project down into the coal as much as 4 or 5 feet. Overlying the black shale is a limestone. Similar black shales overlie other coals and are in turn overlain by limestones, but these coals are almost invariably thin, the accompanying limestone is usually thin, and the presence of the pyrite concretions is not everywhere obvious. There is only one other coal, lying about 300 feet stratigraphically below coal V, whose overlying limestone is thick at many places and which is itself of workable thickness. Its position so far below coal V, however, insures its outcropping well to the east of the outcrop of that coal, so that, although the two have often been confused in the past, there is no danger, with the present knowledge of the coal field, of their being taken for the same coal. Coal V has a thickness of 4 to 10 feet, averaging from 5 to 8 feet over a large part of the area within which it outcrops and maintaining this thickness with considerable uniformity from southwestern Vermilion County, where it enters the State, to Ohio River.

About 70 feet above the top of coal V, in Sullivan County, lies coal VI, ranging in that county from 6 to 8 feet in thickness. Practically everywhere it is divisible into four benches—an upper bench of about 2½ feet, a thin bench of 4 to 6 inches, a lower bench of about 2½ feet, and a bottom bench of 1 foot. The two main benches range from 2 to 2½ feet or more. Between these benches occur gray-shale partings that are nearly everywhere half an inch thick. When exposed to the atmosphere in the entries of the mines this gray shale weathers to a white clay, so that in the mines on this coal bed there appear to be two white chalk marks about midway of the wall at every point. Practically no doubt can therefore exist as to the correlation of this coal within that district. The bottom bench of 1 foot is bony and is usually left in the mine. At the north edge of Sullivan County this coal becomes irregular, in places appearing to run out entirely, and north of that point neither drilling nor mining finds any trace of it in Indiana. It appears to maintain its thickness south of Sullivan County as far as Bicknell and for several miles farther south, though it becomes broken up toward the southwest. From that locality southward it disappears as a regular bed, in many places being entirely absent and in others appearing as a thin bed of 1 or 2 feet. It reaches a workable thickness in a few localities and is commercially worked at two points in Gibson County. Apparently it approaches nearer and nearer to the overlying coal toward the south, until the two range from 20 feet to 6 inches apart, and in at least one place the two coals have been mined together. It will be discussed further in connection with the occurrence of coal VII, in the southern part of the State.

About 40 feet above the top of coal VI in Sullivan County comes coal VII, which is practically everywhere a solid coal from 3 to 6 feet in thickness, overlain by shale or sandstone. North of Sullivan County this bed is readily traced past Terre Haute and through the southwest corner of Vermilion County out of the State. West of Terre Haute and to the north it shows a thickness of 4 to 5 feet of good coal, overlain by 1 to 2 feet of bony coal. A few feet below this coal, in all of the northern part of the coal field, is a limestone that is believed to be one of the persistent members of the coal measures. South of Sullivan County this coal bed can be traced through Wheatland, in the hills west of Petersburg, and on to Ohio River, with a thickness of 4 feet or less, becoming rather thin as Ohio River is approached. As stated above, the underlying coal VI is close beneath it from Gibson County southward, and in one place in western Warrick County they are worked together. In general the limestone below coal VII lies between the two coals, and in many places where the two coals are close together the limestone forms the only parting. This condition continues into western Kentucky, where coal VII is known as Kentucky 12 and coal VI as Kentucky 11. Coal V of Indiana corresponds to coal 9 of Kentucky.

Above coal VII in Indiana, as a rule, only thin coals are found. In a few places these coals reach a thickness of 3 or 4 feet, but in nine out of ten drillings they show thicknesses of less than 2 feet, and commonly less than 1 foot. Small coals occur between coal V and coal IV, and though in some places they reach a thickness of 3 feet, as a rule they are thin, and in the presence of much thicker coals above and below they will not be considered of workable character for a long time.

Coal IV, the bed extensively worked around Linton, is from 100 to 130 feet below coal V. It is commonly a solid coal, with a sandy shale or sandstone roof and a sandstone or sandy clay floor. It shows a tendency to split in many districts, the splitting being in places rather extensive, so that the benches are separated by 10 to 15 feet or more. It can be traced northward to Seelyville, where it is the surface bed, ranging from 3 to 6 feet in thickness, and on to the horseshoe bend of Little Vermilion River, being of workable thickness nearly everywhere, except as it may be broken up by one or more large partings. It is a coal of excellent quality. To the south the thickness of this coal is somewhat less, usually not being more than 3½ feet and toward Ohio River averaging probably less than 2½ feet. In that district it is nearly everywhere a solid coal, with either a shale or a sandstone roof.

About 70 feet below coal IV in Greene County is coal III, a bed 6 to 8 feet thick, almost invariably with one or more regular partings. It maintains this thickness northward through western Clay County and eastern Vigo County, being the large bed worked around Turner and Stanton and the principal bed at Seelyville, Fontanet, and Rosedale. It tends to be a strong steam coal, but in many places has a high content of sulphur. In the Rosedale-Fontanet district the sulphur occurs in the form of one or more regular partings and therefore is more easily separated. North of Coxville this bed occurs in scattered patches for a distance of 6 or 8 miles, beyond which it is absent altogether. South of Greene County no bed of this character is found, and it is possible that the coal runs out entirely. In many places one or more thin coals are found about in the position of coal III, and it has been assumed that they may possibly represent this coal. Few of these thin coals south of Greene County, however, are workable, though here and there they increase to 3 feet in thickness. The coal called the Rock Creek coal in the Ditney folio possibly belongs at the horizon of coal III of Greene County.

About 100 feet below coal III in northeastern Vigo County is a coal bed that is being worked around Fontanet, Minshall, and Mecca, and at other points. It has been called in the trade the Minshall coal, and this name has been retained for it, as it comes below the bed called coal II in the general columnar section. It is a coal of variable thickness, lying in basins and ranging from 5 feet to a fraction of an inch. Overlying it in many places is black shale, which is not everywhere sheety, and above that a heavy limestone. A limestone underlain by a coal that is in some localities of workable thickness occurs at many points through the northern part of the Indiana coal field in Parke, Fountain, and Warren counties. It has been assumed to belong at the horizon of the Minshall coal. In the Brazil district of Clay County this bed has been called the Rider Block coal, as it lies only about 30 feet above the Upper Block coal.

In the Brazil district the two block coals lie about 30 feet apart. Each may have a thickness of about 5 feet in the center of the basins and thin down to a few inches on the hills between the various basins. The Upper Block coal has slightly the greater thickness. It is usually a solid coal, with a 2-inch band of brittle coal a little below the middle. It is also distinguished from the Lower Block coal by the fact that the vertical joints that characterize both the block coals are in the Upper Block coal more open at the top and are indistinct below this brittle "bench mining." The Lower Block coal is a solid coal except for a smooth parting 6 to 10 inches from the top. The coal above that parting is not of the block character. The joints are more open at the bottom and, as a rule, do not penetrate this upper bench of coal. In the center of the basins below the main bench there usually occurs clay, then 1 to 2 feet or more of bony coal, then, locally, up to 2 feet of good coal, with clay underneath. Toward the edges of the basins these underlying benches thin out one at a time, beginning at the bottom, and at the crest of the divide even the lower part of the main coal has thinned out, leaving possibly only the thin upper bench to pass over to the next basin. The two block coals can be traced northward into Fountain County, though the Lower Block appears to be absent in Warren County. The block coals extend southward with their characteristic features into southern Clay County and central and eastern Greene County. South of that region their characteristics have not been recognized, and correlations made with them are only suggestional in character. Through Daviess, Pike, Dubois, Warrick, Spencer, and Perry counties a large number of coals are found, but no extensive drilling and relatively little mining have been done, so that the correlation of these coals from point to point is very uncertain. Furthermore, the fact that they occur in basins, like the coals of corresponding position to the north, means that at many points where they appear they may be only a few inches thick and not recognized as the same coal that may be opened by a country bank a few hundred yards away. The fact that the coal on the divides between the basins ranges from 20 to 50 feet higher than the coal in the center of the basin also confuses any attempt at correlation on the meager information at present in hand. In some areas it has been possible to make correlations for short distances. For example, a coal that is overlain by limestone and that lies about in the position of the Minshall coal in the northern part of the State and was called the Holland coal in the Ditney folio has been recognized on Sugar Creek, in southeastern Daviess County; over a considerable territory south of White River, north and south of Holland, in Dubois County; and around Buffaloville and Newtonville, in Spencer County. Although present knowledge of the coals of these southern counties does not seem to hold out hope of a large coal output, it is quite possible that the coals there, when better known, may show the presence of as much coal in this part of the section as is found in Clay or other more northern counties. In the southeastern part of the coal field is a coal that has been long extensively worked at Cannelton, from which it has been called the Cannelton coal. Like the other coals, it occurs in basins, ranging where present from 4 feet in thickness down. It has been recognized along Anderson River, as far north as St. Meinrad. It is possible that it is the same coal that locally shows a workable thickness around Shoals.

THE WASHBURN LIGNITE FIELD, NORTH DAKOTA.

By Carl D. Smith.

INTRODUCTION.

The Washburn field, a small part of a large area of lignite-bearing rocks of Tertiary age which covers the western half of North Dakota, comprises parts of McLean, Oliver, Mercer, and Burleigh counties and lies a short distance to the southwest of the center of the State, 40 miles up Missouri River from Bismarck. (See fig. 1.) The investigation of this field was undertaken primarily to obtain information

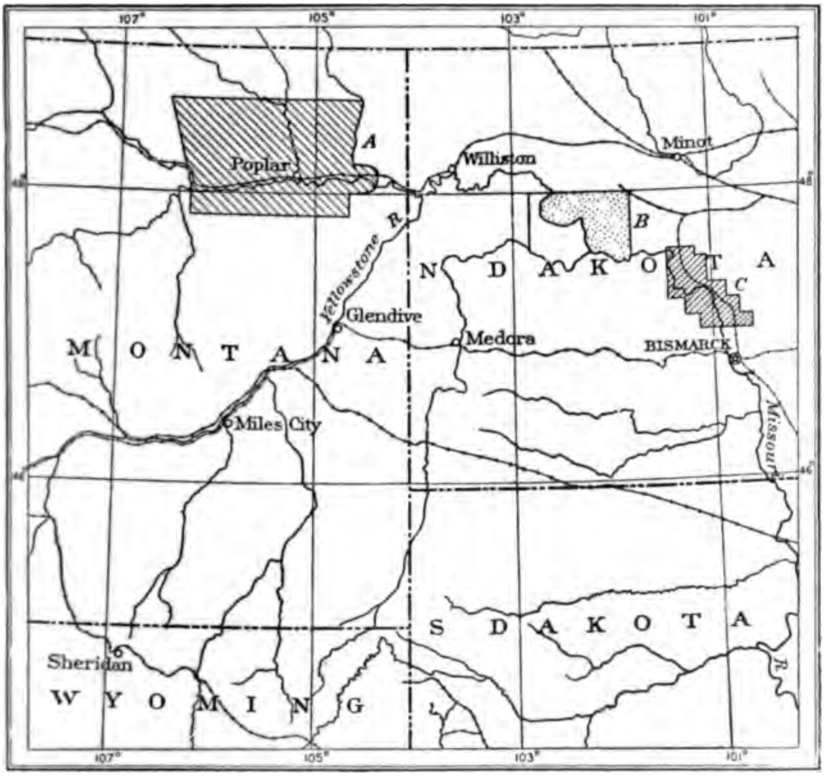


Figure 1.—Index map showing location of Washburn (*C*), Fort Berthold Indian Reservation (*B*), and Fort Peck Indian Reservation (*A*) lignite fields, North Dakota and Montana.

regarding the character, depth, and horizontal distribution of lignite beds within reach of irrigable lands along Missouri River, which it is proposed to water by pumping, with lignite as fuel.

That part of the field east of Missouri River is traversed by a branch of the Minneapolis, St. Paul and Sault Ste. Marie Railway. A projected branch of the Northern Pacific Railway, leaving the main line at Mandan, follows closely the west bank of the Missouri through the field. At certain seasons the river furnishes transportation to and from the region.

Acknowledgments are due to Mr. Jay W. Bliss for his able assistance in the field work, and to Mr. T. R. Atkinson, state engineer, for additional notes and data concerning lignite near Wilton.

TOPOGRAPHY.

The field is mainly a smooth, rolling prairie with bluffs and badlands here and there along the larger streams. The elevation of the water surface of the Missouri at ordinary stage at Washburn is 1,656 feet above sea level. Away from the immediate valley of the Missouri the general elevation averages from 200 to 350 feet higher than the river.

The presence of glacial material left by the retreat of the great ice sheet, which covered this part of the State in comparatively recent geologic time, has no doubt had a tempering effect on the topography. In other parts of the State, beyond the limit of glaciation, where conditions are otherwise similar to those around Washburn, badlands topography is common along the larger streams. Although the direct effects of glaciation are not now apparent, probably on account of the softness of the local formations and the consequent rapid weathering, indirect results appear in numerous intermittent lakes and abandoned stream channels.

GEOLOGY.

STRATIGRAPHY.

All the stratified rocks described here belong to the Fort Union (early Eocene) formation. In the past these rocks have been generally referred to the Laramie (Cretaceous), but later work in the region has proved that they are Tertiary. The formation consists of sands, clays, and sandy clays, in about equal proportion in alternating layers, with beds of lignite scattered throughout. The clays and sandy clays are usually dark gray or somber in color; the sands and sandstones vary in shade from light blue to buff. All of this material, except local sandstone lenses and irregular sandstone layers, is soft and weathers rapidly.

Overlying the Fort Union formation is a mantle of glacial drift, varying greatly in thickness and made up of a variety of materials foreign to this general region. It is usually covered by soil, but in places erosion has tended to segregate the bowlders at the bases of steep slopes or has partly swept away the soil, thus leaving the bowlders on or near the surface. They vary in size from mere pebbles to masses several feet in diameter and are used principally for building foundations.

STRUCTURE.

So small an area was covered by this investigation that little can be said of its structure. Evidence now in hand, however, indicates that there is a slight dip of the formations toward the east, probably not more than 2 feet to the mile. This is inferred from the fact that a bed of lignite, which is low in the section on the west side of the field dips beneath the river toward the east. So far as mining is concerned the lignite beds and containing formations may be regarded as lying flat.

THE LIGNITE.

GENERAL STATEMENT.

By reference to the columnar section on the map accompanying this report (Pl. I) it will be seen that workable beds of lignite occur at six horizons in the 315 feet of strata lying above river level. The exact relation of the beds mined at Wilton to those about Washburn is not known, but it is thought that they are slightly higher. No records of deep wells in this area have been obtained, hence it is impossible to say anything positive concerning lignite beds that may underlie the field at greater depths than river level. It is probable, however, that many workable beds of lignite could be found to a depth of 1,500 feet.

Heretofore the lignite beds of this general region have been described as lenticular and impossible of correlation for distances exceeding 2 or 3 miles. It is true that the lignite varies considerably in thickness from point to point, but the term "lenticular" is misleading and considerable work in this general field has proved that some of the more important beds can be correlated or even traced in their outcrops for much greater distances than 2 or 3 miles.

Many outcrops of lignite beds, covered by glacial material or talus, are marked by springs and seepages. Beds of lignite seem to be the best carriers of underground water. This is probably due to the variable character of the sands and clays which make up the section. Although a formation at a certain horizon may be in one place a porous sand well adapted to carrying water, its character may so change within a short distance horizontally that water can not find its way through. In this way the lignite beds, which are fairly homogeneous in texture and more persistent laterally than other formations, become the water-bearing beds.

The accompanying map (Pl. I) shows the locations of the principal mines and prospects in the field, with a columnar section indicating the vertical distribution of the various beds of lignite. This section was compiled from widely separated exposures, and it is not to be assumed that fuel will be found at a given elevation in all parts of the area.

It is quite probable that a number of lignite exposures and mines not represented on the map are to be found in the field. As few townships as possible have been used to show the general connections of the different districts discussed and the positions of the railroads. Hence, if any mines in the field are not here discussed, the omission is due not to oversight but to lack of time in which to visit them.

DETAILED DESCRIPTION OF LIGNITE EXPOSURES.

A few representative detailed sections of lignite beds in the area covered by this report are given in the following pages.

OLD COAL HARBOR DISTRICT.

Joe Mann mine.—At the base of the bluff in the NW. ¼ sec. 34, T. 147 N., R. 84 W., lignite is being mined at present. The method used is a combination of stripping and drifting.

Section at Joe Mann mine.

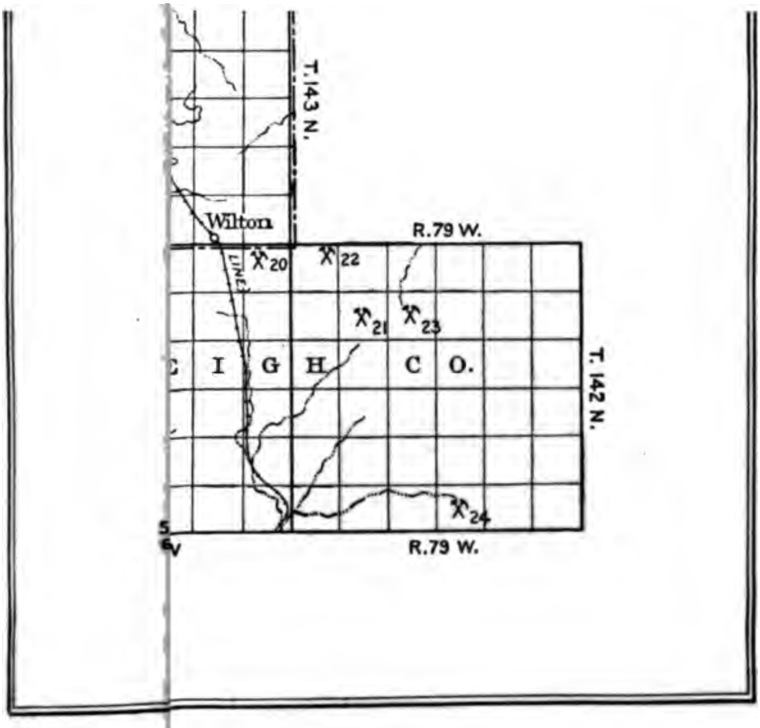
Clay roof.	Ft.	in.
Lignite	2	10
Clay		6
Lignite	4	6
Clay, sandy	1	2
Lignite	2	5
Total lignite	9	9

Both up and down the river from this locality the lignite has been burned along its outcrop, producing a red clinker. A short distance north of the mine the lignite is on fire at present. Its horizon lies from 15 to 30 feet above water level at ordinary stage. The fuel is mined for local neighborhood use and is delivered by wagons.

Eskes mine.—About 1 mile southwest of the Joe Mann mine, in the NE. ¼ sec. 4, T. 146 N., R. 84 W., Eskes & Son are stripping a bed of lignite in the face of the bluff, 50 feet above the bed at the Joe Mann mine.

Section at Eskes mine.

Clay roof.	Ft.	in.
Lignite	2	7
Clay and lignite		2
Lignite	2	6
Total lignite	5	1


T.143 N.
Wilton
R.79 W.
LINE
20
22
21
23
C I G H C O.
T. 142 N.
24
5
6
V
R.79 W.

The outcrop of this bed can be easily followed to the south for 4 or 5 miles. At several places it has been stripped and is marked by a fringe of clinker, having been burned. The bed is extremely variable in thickness, its position in the section at other localities being occupied by bituminous clay or thin, valueless seams of lignite.

Marion mine.—In the SW. ¼ sec. 26, T. 145 N., R. 84 W., an entry has been driven on the Joe Mann bed of lignite, which is easily traceable from the Joe Mann mine southward to the Marion mine by the clinker produced by burning along its outcrop. The section at the Marion mine shows 7 feet 9 inches of lignite, with clay roof and clay floor.

About one-fourth mile south of the Marion mine another entry is being driven on the same bed, the thickness being about the same.

A short distance south of these openings the outcrop of this bed of lignite, as marked by the clinker, disappears below the lowland bordering the river, and was not seen again in the field.

The writer did not visit the region west of the river opposite the points mentioned above. F. A. Wilder[a] gives the following measurements of beds seen along the bluff from Mannhaven to Stanton:

Section near Mannhaven.

	Feet.
Lignite, good	6
Clay	2
Lignite	1
Clay	1
Lignite, good	2
Clay	10
Lignite, good	8
Sand to river level	10
Total lignite	17

Wilder states that this section may be seen for 2,000 feet along the river.

Section 3 or 4 miles south of Mannhaven.

	Ft.	In.
Lignite	3	
Clay		6
Lignite	3	
Clay	2	
Lignite	3	
Total lignite	9	

This bed probably represents the upper part of the section at Mannhaven.

According to Wilder a 7-foot bed outcrops near river level at the edge of the flat 2 miles above Stanton. This bed doubtless corresponds to the bed seen by the writer at the Marion mine, east of the river, opposite Stanton.

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[a] The lignite of North Dakota and its relation to irrigation: Water-Supply Paper U. S. Geol. Survey No. 117, 1905.

WASHBURN DISTRICT.

Pfister & Cramer mine.—At an elevation of 250 feet above river level, in the NE. ¼ sec. 36, T. 145 N., R. 83 W., Pfister & Cramer are mining a bed of lignite by stripping. The bed measures 6 feet thick, but the upper 1½ feet is weathered and worthless.

Satterlund mine.—At an elevation of about 180 feet above the level of Missouri River occurs a bed of lignite, which is for convenience of reference called the Fairman bed. It is exposed at a number of places about Washburn. The Satterlund mine, in the NE. ¼ SE. ¼ sec. 1, T. 144 N., R. 83 W., is probably on this bed.

Section at Satterlund mine.

Clay roof.	Ft.	in.
Lignite	7	
Clay		½
Lignite	2	
Clay		3
Lignite (thickness reported)	1	6
Total lignite	10	6

The cover above the lignite is here 25 to 40 feet thick. The mine is operated by a drift 400 feet in length, and its output amounts to 30 or 40 tons a day. The product is consumed by residents of Washburn and vicinity.

Phippen mine.—Northeast of the Satterlund mine, in sec. 35, T. 145 N., R. 82 W., lignite is being taken out at present by stripping. The mine is known locally as the Phippen mine, and is probably in the same bed as the Satterlund. At the time this mine was visited only the lower part of the bed could be seen. A section of the part of the bed exposed shows 5 feet 4 inches, including two partings.

Section at Phippen mine.

Débris roof (top of bed not seen).	Ft.	in.
Lignite		8+
Clay		4
Lignite	2	8
Clay		5
Lignite	1	3
Total lignite	4	7+

Lignite is mined here to supply local demands, and is variously reported from 6 to 14 feet thick. A considerable area about the mine is underlain by this bed, but the cover is relatively light.

On the point of the hill west of the wagon road, in sec. 8, T. 144 N., R. 82 W., an opening has been made at the horizon of the Fairman bed, 180 feet above river level, but the lignite was found to be replaced by several feet of carbonaceous clay, or "black jack."

In the river bluff south of Conklin the stratigraphic position of the Fairman bed is occupied by two thin beds separated by a large parting. The lignite is here burned along its outcrop for several miles and may be locally workable. Near old Coal Harbor the horizon of the Fairman bed is occupied by thin, worthless seams of lignite.

Old Fairman mine.—Lignite at the old Fairman mine, in the NE. ¼ sec. 27, T. 143 N., R. 81 W., shows a thickness of 7 feet of apparently good coal, with two thin partings.

Section at Fairman mine.

Clay roof.	Ft.	In.
Lignite	1	3
Clay		6
Lignite	1	6
Clay		3
Lignite	3	6
Total lignite	6	3

Due south of the old Fairman mine, in sec. 3, T. 142 N., R. 81 W., is a partial exposure of a bed of lignite at the same elevation, which is taken to be a continuation of the Fairman bed. Its thickness at this locality could not be measured.

Between the Fairman bed and Missouri River level, in the Washburn district, no lignite of any consequence has been observed. A bed 75 feet above water level has been mined by Mr. Petersen at his house, in sec. 24, about 1 mile southeast of Washburn. The bed here varies in thickness from 1½ to 2 feet and is underlain by 4 feet of "black jack" or bituminous shale. In a small draw which runs southward through sec. 8, T. 144 N., R. 82 W., a number of seepages indicate that one or two beds of lignite, probably thin, are to be found about 50 feet above river level.

DISTRICT SOUTH AND WEST OF MISSOURI RIVER.

Van Epp mine.—A bed of lignite that corresponds in elevation to the Fairman bed is mined by stripping in the SE. ¼ sec. 10, T. 143 N., R. 82 W., 3 miles south of Hensler post-office. The bed is 6 feet 4 inches thick, without partings. One mile northwest of this opening are two others, one in sec. 10, the other in sec. 9, both of which show 5 feet of clean, hard lignite. These are doubtless on the same bed as the Van Epp mine.

Old Cogan and other mines.—About 6 miles west of the above-mentioned locality, in the SE. ¼ sec. 8, T. 143 N., R. 83 W., a bed of lignite at the same horizon was formerly mined by stripping at the Cogan mine, but the workings have been abandoned and have caved in. The bed measures 3 feet 10 inches and is very hard and free from partings. About 1 mile east of Cogan's mine, near the middle of sec. 9, an opening on the same bed shows a thickness of 3 feet 9 inches. Fuel is mined here for local use.

In the SE. ¼ sec. 2, T. 143 N., R. 83 W., a bed of lignite 100 feet above Missouri River is mined for local use. The bed is 4 feet 4 inches thick, with a 2-inch parting 4 inches from the bottom.

Along the gulch which runs northward through secs. 17, 8, and 5, a short distance west of Cogan's mine, lignite varying in thickness from a few inches to 3½ feet outcrops in many places.

Along an eastward-flowing stream in the northern part of sec. 7, T. 142 N., R. 81 W., lignite is being mined for local use from three small strip pits. In the easternmost of these pits the bed measures 3 feet 6 inches, but is said to contain much "slack" or dirty lignite. There are probably two beds here, the upper being mined farther west, up the draw. These beds are about 80 feet above river level, and are probably the same as the beds noted near the mouth of Mandan Lake Creek at the same elevation.

In the NE. ¼ sec. 4, T. 143 N., R. 83 W., about half a mile southwest of Mandan Lake, 50 feet above river level, a bed of lignite 2 feet thick was measured. About half a mile south of Mandan Lake, in sec. 3, a bed of lignite has been mined by stripping. It is about 100 feet above river level. The whole thickness of the bed was not seen, but it is at least 2 feet 6 inches thick.

WILTON DISTRICT.

For information concerning mines in the Wilton district the writer is indebted to Mr. T. R. Atkinson, state engineer of North Dakota. In 1907 the Washburn Lignite Coal Company's mine was visited by the writer, but its location and additional data as to the output and equipment have been furnished by Mr. Atkinson.

The exact relation of the deposits mined about Wilton to those near Washburn is not known, but it is believed that they are slightly higher in the geologic section.

Washburn mine.—The Washburn mine, in sec. 1, T. 142 N., R. 80 W., is the largest and most thoroughly equipped mine in the State. Its output for 1907 and 1908 amounted to 109,992 tons. The lignite is reached by a shaft 60 feet deep, which represents the average thickness of the cover. The underground equipment is very complete and efficient and consists of electric undercutting machinery and electric motors for haulage. The lignite ranges from 8 to 13 feet in thickness, and has a variable parting 1½ feet from the bottom. The entries are unusually wide, and timbering is necessary. As a rule, 6 or 8 feet of the bed is taken out first, leaving lignite for a roof, which is taken down when pillars are pulled.

Eckland mine.—In sec. 8, T. 142 N., R. 79 E., is a small opening known as the Eckland mine. The lignite is about 8 feet thick, and has about 45 feet of cover. The annual production is 800 tons.

Lind mine.—In the NE. ¼ sec. 6, T. 142 N., R. 79 E., at the Lind mine, the lignite is 11 feet 10 inches thick, under a cover of 35 feet. The production is about 700 tons annually.

Peterson mine.—In sec. 9, T. 142 N., R. 79 E., at the Peterson mine, the bed is 11 feet thick, under a cover of 40 feet. The annual production is about 2,000 tons.

Yiengst mine.—At the Yiengst mine, in sec. 34, T. 142 N., R. 79 E., the lignite is 6 feet thick, under 60 feet of cover. The roof and floor are clay. The annual output is about 1,000 tons.

CHARACTER AND USES OF THE LIGNITE.

GENERAL CHARACTER.

The lignite of this field is dark brown in color and tough and woody in structure, but the woody structure is not so evident as in lignite from other parts of the State. It slacks rapidly on exposure to air and sunlight, especially when much handled or subjected to long hauls by rail.

The impurities in the lignite consist mainly of sand and clay partings, which are difficult of separation in mining. Intimate mixtures of fine sand or clay and lignite, of irregular shape and extent, are rather common in the beds and are not easily detected without close examination, as they have the same color as the lignite.

On weathering, the lignite, which is usually lusterless and massive, breaks into small, shiny cubical blocks, which appear black, but give a brown streak or powder.

Because of the scarcity of timber in this general region lignite is almost the only fuel available for domestic purposes. The state institutions use native lignite exclusively, and to supply this demand, together with a growing demand from manufacturing plants, several well-equipped mines are in operation on main lines of transportation in various parts of the State.

LIGNITE AND IRRIGATION.

The impracticability of irrigating lowlands along the Missouri by gravity canals has led to the establishment of a pumping plant at Williston, N. Dak., and to the investigation of many other projects for raising water to the desired elevations with lignite as fuel. Two such projects in the Washburn field are now under consideration by the United States Reclamation Service. It is, of course, desirable that lignite be found within easy reach of the proposed location of pumping stations, but this can not always be done, notwithstanding the general distribution of the fuel. However, there are relatively few irrigable flats along the Missouri between Bismarck and the North Dakota-Montana line where lignite can not be found in minable thickness either at hand or within a few miles.

CHEMICAL ANALYSES AND STEAMING AND PRODUCER-GAS TESTS.

The following analyses and tests[a] were made at the Geological Survey's fuel-testing plant in St. Louis:

Brown lignite from Wilton mine, Washburn Lignite Coal Company, 1 mile east of Wilton, McLean County, N. Dak., on the Minneapolis, St. Paul and Sault Ste. Marie Railway.

This sample was made up of lump lignite and was shipped under the supervision of M. R. Campbell, of the United States Geological Survey. It was used in making steaming test No. 206 and producer-gas test No. 67.

Mine samples Nos. 1935 and 1938 were taken at widely separated points in the mine for chemical analysis.

Analyses of samples as received.

		Mine samples.		Car sample, Laboratory No. 2243.
		Laboratory No. 1935.	Laboratory No. 1938.	
Air-drying loss		32.30	33.50	12.70
Prox.	Moisture	40.53	41.88	35.96
	Volatile matter	27.05	26.11	31.92
	Fixed carbon	27.37	26.73	24.37
	Ash	5.05	5.28	7.75
Ult.	Sulphur	.76	.96	1.15
	Hydrogen			6.54
	Carbon			41.43
	Nitrogen			1.21
	Oxygen			41.92
Calorific value determined:				
	Calories	3,691		3,927
	British thermal units	6,644		7,069

STEAMING TEST.

Test 206, North Dakota No. 3.—Size as shipped, lump. Size as used, average diameter 3 inches, 76.5 per cent; ½ inch to 1 inch, 10.6 per cent; ¼ inch to ½ inch, 4.9 per cent; under ¼ inch, 8 per cent. Duration of test, 5.72 hours. Kind of grate, rocking.

		Test 206.
Heating value of coal	B. t. u. per pound dry coal	11,036
Force of draft:		
Under stack damper	inch water	0.65
Above fire	do	[b].10
Furnace temperature	°F	2,093
Dry coal used per square foot of grate surface per hour	pounds	27.99
Equivalent water evaporated per square foot of water-heating surface per hour	do	3.24
Percentage of rated horsepower of boiler developed		90.7
Water apparently evaporated per pound of coal as fired	pounds	3.52
Water evaporated from and at 212° F.:		
Per pound of coal as fired	do	4.13
Per pound of dry coal	do	6.45
Per pound of combustible	do	7.47
Efficiency of boiler, including grate	per cent	56.44
Coal as fired:		
Per indicated horsepower hour	pounds	6.85
Per electrical horsepower hour	do	8.46
Dry coal:		
Per indicated horsepower hour	do	4.38
Per electrical horsepower hour	do	5.41

[a] Bull. U. S. Geol. Survey No. 290, 1905, pp. 138, 139.

[b] Forced draft.

PRODUCER-GAS TEST.

Test 67, North Dakota No. 3.—Size as shipped, lump. Size as used, over 1 inch, 85 per cent; ½ inch to 1 inch, 6 per cent; ¼ inch to ½ inch, 3 per cent; under ¼ inch, 6 per cent. Duration of test 50 hours.

Average electrical horsepower	195.5
Average B. t. u. gas per cubic foot	158.9
Total coal fired, pounds	30,250

	Test 67.		
	Coal as fired.	Dry coal.	Combustible.
Coal consumed in producer (pounds per horsepower per hour).			
Per electrical horsepower:			
Available for outside purposes	3.27	2.10	1.89
Developed at switchboard	3.10	1.99	1.79
Per brake horsepower:			
Available for outside purposes	2.78	1.78	1.61
Developed at engine	2.63	1.69	1.52
Equivalent used by producer plant (pounds per horsepower per hour).			
Per electrical horsepower:			
Available for outside purposes	3.42	2.20	1.98
Developed at switchboard	3.24	2.08	1.87
Per brake horsepower:			
Available for outside purposes	2.92	1.87	1.68
Developed at engine	2.75	1.77	1.59

Briquetting tests of North Dakota lignite have been made by the United States Geological Survey fuel-testing plant and by individuals. No binder is used, but the product is firm and gives excellent results except when subjected to forced draft, which has the effect of disintegrating the briquets and carrying the unburned particles out through the smokestack.

Another consideration that adds materially to the value of the brown lignite is its surprising success in the producer-gas plant. The following statement has been made concerning the value of North Dakota lignite in the gas producer and gas engine:[a]

> The result of the steam test was so unsatisfactory that there is nothing by which a direct comparison can be made of the efficiency of the fuel used in the producer-gas plant as compared with the efficiency developed in the steam plant. Nevertheless a comparison of the results obtained on other coals under the steam boiler is instructive. The table shows that to produce one electrical horsepower hour in the producer-gas plant required 2.29 pounds of dry North Dakota lignite, whereas to produce the same result in the steam plant required 3.39 pounds of the best West Virginia coal. This means that North Dakota lignite, with the moisture eliminated, will do more work when used in a producer-gas plant than the best coal of the country will do in a steam plant.

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[a] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, p. 111.

THE FORT BERTHOLD INDIAN RESERVATION LIGNITE FIELD, NORTH DAKOTA.

By Carl D. Smith.

INTRODUCTION.

The Fort Berthold Indian Reservation, in North Dakota, about 1,500 square miles in area, is divided approximately in half by Missouri River and lies about midway between Bismarck and the point where the Missouri enters the State. In this paper only the part of the reservation north of the river is considered, and as the area lies wholly within the large region of lignite-bearing rocks which covers the western half of North Dakota, it has no natural boundaries. (See fig. 1.)

Heretofore this region has been remote from any railway, but recently a branch of the Minneapolis, St. Paul and Sault Ste. Marie Railway has been extended northwestward from Washburn, crossing the extreme northeast corner of the reservation. The Missouri River Railway, a proposed branch of the Northern Pacific, leaving the main line at Mandan, will follow closely the south bank of the Missouri, if built as surveyed. At certain seasons of the year Missouri River furnishes transportation to and from the field.

The writer was efficiently assisted in the field work on which this paper is based by J. A. Davis, E. B. Hopkins, E. L. De Golyer, and Jay W. Bliss. Mr. De Golyer also assisted in the office work.

TOPOGRAPHY.

The region is essentially a smooth plain into which the Missouri has cut a valley varying in width from 1 to 2 miles and in depth from 100 to 500 feet. At many points along the river the change from the smooth uplands to the river valley is abrupt and is marked by a narrow strip of bluffs and badlands. At other points, especially where the larger streams enter the river, the gradation is gradual.

The field considered here lies within the area once covered by the great continental glacier, whose effect on the topography is everywhere noticeable. In other parts of this general region, beyond the limit of glaciation, where the surface is not protected by the mantle of drift left by the retreating ice sheet, the territory bordering larger streams is in general minutely dissected into a badland belt several miles in width. In the glaciated area the mantle of drift has so tempered erosional action that badlands appear only where degradation has been extremely rapid.

Intermittent lakes occupying depressions that were probably former stream valleys are also features of the region due to glacial action. The valley of Missouri River between the mouth of Little Knife Creek, at the north boundary of the reservation, and the mouth of Shell Creek is comparatively narrow, indicating that it is probably new. It is probable that the river formerly occupied a depression which now lies in a straight line between the mouths of Little Knife and Shell creeks. Another depression southwest of this one, but joining it at the mouth of Shell Creek, may represent a second abandoned valley of the Missouri before it reached its present position.

GEOLOGY.

STRATIGRAPHY.

All the stratified rocks in the reservation are of Fort Union (early Eocene) age. Heretofore they have been classed as "Laramie and Fort Union" without differentiation, but recent investigations in this general region have proved conclusively that they are Tertiary and they probably correspond to the upper part of the so-called "yellow beds" in the Sentinel Butte field of North Dakota, the Miles City field of Montana, and the Sheridan field of Wyoming. In this region the beds present a rather monotonous sequence of somber-colored clays and sandy clays interstratified with buff sands and sandstones and beds of lignite. The clays and sandy clays predominate, thus lending to the whole series a somber hue. The sandstones are usually fine grained and soft, but at many places they contain irregular concretion-like masses of hard sandstone of the same color and texture as the matrix.

The greater part of the field is overlain by a mantle of glacial drift of Wisconsin age. This material is of variable thickness and contains a variety of rocks foreign to the region.

The following detailed section, made at the big bend of Missouri River 10 miles above the mouth of Shell Creek, gives some idea of the character of the Fort Union formation:

Section at big bend of Missouri River.

	Ft.	in.
Débris	5	
Sand, cream colored	20	
Lignite	1	8
Clay	1	3
Lignite	1	8
Clay	5	5
Lignite	3	9
Clay, somber, sandy, contains irregular masses of hard sandstone, some thin lignite seams, and carbonaceous layers	160	
Lignite	4	6
Clay, somber, comewhat sandy	16	
Clay, carbonaceous, with lenses of lignite	2	
Clay, somber, sandy	5	
Clay, yellowish, with sandstone lenses	8	
Clay, carbonaceous	1	
Sand, clayey	23	
Clay, somber, sandy	5	6
Clay, gray	17	
Clay, carbonaceous		4
Lignite		6
Clay, carbonaceous	1	6
Lignite	2	10
Clay, gray	2	
Clay	5	
Clay, yellowish, sandy	6	
Lignite	1	
Clay, yellowish	14	
Sand, yellowish, clayey, some carbonaceous clay	5	6
Lignite	7	2
Clay, greenish gray with carbonaceous streaks	17	
Sand, somber, clayey, contains ferruginous layers	17	
Clay, greenish gray	10	
Clay, somber, sandy	7	
Clay, greenish, white sand at top	6	
Sand and clay, somber	18	
Lignite		9
Clay, carbonaceous	1	
Lignite	1	1
Clay, carbonaceous	2	6
Clay, bluish	4	
Lignite	1	6
Clay, bluish	15	
Clay, carbonaceous	1	
Clay, sandy, somber	10	
Clay, carbonaceous	4	
Clay, sandy, somber, contains hard sand in places	55	
Lignite	1	

	Ft.	In.
Clay, carbonaceous		6
Clay, sandy, somber, upper 6 feet contains thin seams of lignite	18	
Lignite	1	6
Clay	3	
Sand, somber	12	
Clay, somber, sandy, contains thin lignite seams	35	
Lignite	1	6
Sand, clayey	25	
Clay, somber, with thin seams of lignite	40	
Lignite	5	
Clay	5	
Lignite	7	
Clay and sand, reddish brown at base	100	
Lignite	14+	
Water level in river.		
	765	11+

The members of this formation are extremely variable horizontally as well as vertically. No particular sandstone or clay bed can be selected as a key rock for purposes of correlation from one part of the field to another. Lignite beds, on account of their greater persistence laterally than the containing rocks, furnish the only means of correlation, and they are uncertain where large areas between outcrops are concealed.

STRUCTURE.

The strata of the reservation lie almost horizontal. At some places, however, evidence of a slight eastward dip is unmistakable. This was discovered by tracing some of the more persistent lignite beds whose outcrops as followed downstream either approach or dip below river level. The dip is not constant in degree. There are broad areas where the strata lie horizontal, the whole thus constituting a series of gentle undulations. The amount of the dip at any point is very little more than the fall of the river, and so far as mining operations on a small scale are concerned it may be disregarded.

THE LIGNITE.

GENERAL DESCRIPTION.

Lignite beds occur at intervals throughout the rock section exposed. They are variable in thickness and horizontal extent, but as some of the important beds have been traced continuously for 12 miles by their outcrops they can not justly be described as lenticular. The covering of glacial drift has prevented the tracing or correlation of beds from one part of the field to another. No direct evidence has been obtained as to the thickness of lignite-bearing strata that may underlie the field at a greater depth than river level, but observations made in this same general region lead to the belief that workable beds of lignite can be found to a depth of 1,000 feet or more.

On account of the smooth character of the country no exposures of lignite were noted in the uplands away from the breaks of the river, but it is probable that lignite beds occur there and could be found by prospecting.

As lignite is more or less porous and jointed it is a much better medium for the travel of underground water than the fine-grained variable clays and sands which make up the rest of the section. It happens, therefore, that at many places springs and seepages mark the outcrops of lignite beds that are covered by débris.

Wherever exposed in the badlands the thicker beds have been burned along their outcrops, producing a red clinker which consists of baked and partly fused sands and clays. The material immediately underlying a burned-out bed is only slightly affected, while the material overlying it may be metamorphosed for a thickness of 20 or 30 feet, depending on the thickness and purity of the bed burned. It is evident, then, that in prospecting for a bed of lignite where its outcrop is fringed by clinker, the base of the clinker, which is usually well marked, will be found on a level with the unburned body of lignite. The distance back from the outcrop of a bed to which burning may take place depends on the thickness of the cover, but in this connection it is difficult to give exact figures. To an observer it is at many places an obvious matter. The persistence of clinker along an outcrop serves to some extent as an index to the character of the bed burned, as thick, pure beds are more apt to burn than thin, impure ones.

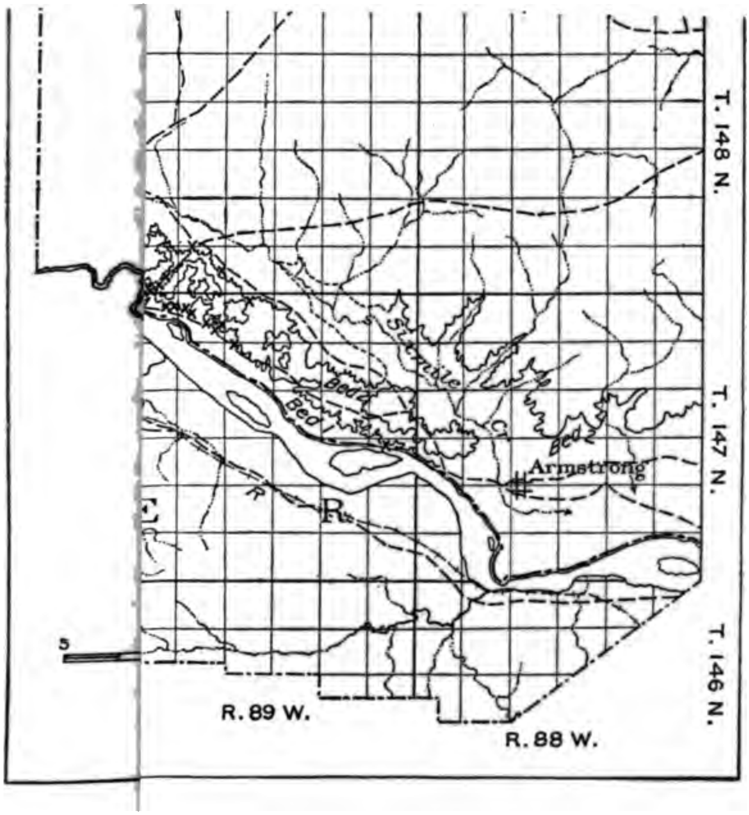
The outcrops of the important beds in this field have been traced and are shown on the map (Pl. II). The outline of the whole reservation is shown, but little is known of the region south of the river except that its topography is considerably rougher than on the north side.

DISTRIBUTION OF THE LIGNITE.

The lignite beds will here be described by districts, beginning at the north boundary of the reservation and following in order down the Missouri to the east boundary.

BIG BEND DISTRICT.

After entering the reservation the Missouri makes a U-shaped bend which terminates near the mouth of Shell Creek. This bend is bordered by high bluffs in which a number of lignite beds ranging in thickness from a few inches to more than 14 feet have been observed. Only four of these beds are of sufficient thickness for mining.


T. 148 N.
T. 147 N.
T. 146 N.
Bed 4
Bed
Cr.
Bed 2
Armstrong
R
E
R.
5
R. 89 W.
R. 88 W.

Bed 1.—The lowest bed, more than 14 feet thick, is exposed in the west bank of Missouri River, opposite and a short distance below Wiedeman's ranch. Water in the river at ordinary stage conceals the base of the bed and at flood time covers it completely. The exposure of the bed is due to an eastward-pitching anticline of local extent, and it disappears below river level both up and down stream within a few hundred feet of the point where it was measured. The portion of the bed seen is free from partings and appears to be of excellent quality.

Bed 2.—The next bed of consequence exposed in the big-bend district lies about 100 feet stratigraphically above bed 1. Its outcrop has been traced from a point 1 mile below the mouth of Little Knife Creek, at the north boundary of the reservation, to a point 2½ miles south of Wiedeman's ranch, and is shown on the map (Pl. II). North of Wiedeman's the bed is in one bench, 4 to 5½ feet thick, and lies from water level to 30 feet above. Its outcrop is in the base of the bluff which forms the east bank of the river and is therefore everywhere near the river. For this reason the bed is almost inaccessible to any means of transportation except by water. Local landslides caused by the undermining action of the river against its bank have broken great masses of lignite from the bed, and these, after being washed clean of sand and clay, lie exposed on the bank. Steamboats plying the river frequently stop here for the fuel which can be so easily obtained.

South of Wiedeman's ranch the outcrop of bed 2, which is there made up of two benches, has been traced for about 2 miles. The effect of the local anticline mentioned in connection with bed 1 is felt by bed 2, which for a mile or so rises to an elevation of 50 feet above the river.

Section of bed 2 about 2 miles south of Wiedeman's ranch.

	Ft.	In.
Clay roof.		
Lignite	4	6
Clay, sandy	4	9
Lignite	3	5
Clay		3
Lignite	3	5
Concealed to river level.		
Total lignite	11	4

Near the point where the river turns from a southward to an eastward course bed 2 disappears beneath the hill wash that borders the bottom lands along the river, and was not seen again in the field. Except for a few thin partings bed 2 is comparatively clean, and its quality seems to be good.

Beds 3 and 4.—In the badlands bordering the river between Wiedeman's ranch and the mouth of Shell Creek beds 3 and 4 are exposed and their thicknesses are sufficient to deserve some notice. These beds are 300 and 375 feet, respectively, above river level. They vary considerably but have not been observed to exceed 4 feet 6 inches in thickness. Immediately south of Wiedeman's they are thin and worthless. They appear to reach their greatest thickness a few miles west of the west line of T. 150 N., R. 92 W. These upper beds are well exposed on the south side of the high bluff, but glacial drift so conceals their northern outcrops that their positions are indefinite. It will be seen from the map (Pl. II), where their outcrops are shown, that these two beds are outliers, cut off from the region to the north by the low depression which lies between Wiedeman's ranch and Shell Creek.

North of Wiedeman's ranch a part of the outcrop of bed 3 has been traced and is shown on Plate II. The bed has not been observed to exceed 4 feet in thickness and lies near the top of the bluff 300 feet above river level.

South of a small stream which flows westward into the Missouri, about 1 mile south of the north boundary of the reservation, lignite is exposed in several places, and is 2½ to 3½ feet thick.

LOQUEMONT CREEK DISTRICT.

About 4 miles north of the mouth of Loquemont Creek the Missouri swings against its east bank, forming a bluff in which several beds of lignite are exposed. A section of the bluff follows:

Section 4 miles north of mouth of Loquemont Creek.

	Ft.	in.
Débris.		
Clay, carbonaceous	4	
Sand, clayey	65	
Clay, carbonaceous	4	
Lignite	5	11
Sand and clay with some thin lignite seams	100	
Lignite	1	6
Clay	5	8
Lignite (poor)	3	3
Clay	5	
Lignite	2	10
Concealed to river level	50	
	247	2

The lower beds of the foregoing section are exposed at several places near the wagon road which runs between the bluff and the river. The upper bed appears well up in the bluff, or 170 feet above river level. Its outcrop, shown on Plate II, has been traced for 6 or

8 miles, and in places it has been burned. It is 5 to 6 feet thick and seems to be of good quality. Near the mouth of Loquemont Creek it is so concealed that no measurements could be made. The position of the bed makes it easily accessible for mining purposes, and is such that it must underlie a large territory to the east, if it is continuous in that direction.

ELBOWOODS DISTRICT.

Between Elbowoods and the mouth of Sixmile Creek the north bank of Missouri River is bordered by a strip of badlands from 1 to 2 miles wide, in which several beds of lignite are exposed. They are nearly everywhere fringed by clinker produced by combustion along their outcrops. Two of them have been mapped, and for convenience of reference are designated as beds 1 and 2.

Section 5 miles east of Elbowoods.

	Ft.	In.
Sand, somber, clayey	50	
Lignite	3	
Clay, sandy	8	
Lignite	4	
Clay, somber	34	
Lignite (bed 2)	6	6
Clay, somber	20	
Lignite	1	
Clay, somber	9	
Lignite	2	
Sand and clay, some carbonaceous layers	35	
Sand with irregular hard lenses	45	
Lignite (bed 1)	7	
Clay, somber, sandy	22	
Lignite	1	9
Clay, gray	1	4
Lignite	2	7
Clay, somber, sandy	14	5
Concealed to river level, about	60	
	326	7

Bed 1.—At a point about 4 miles east of Elbowoods, where Missouri River swings to the north against the badland bluffs, bed 1, the lowest considered in the section, is about 70 feet above water level, or 50 feet above the flood plain of the river. To the southeast it outcrops in the base of the bluff everywhere near the edge of the river flat, and dips gradually eastward to the western part of T. 147 N., R 88 W., where it disappears below the alluvium. The bed is nearly everywhere fringed by clinker and for that reason is easily traceable. Near Elbowoods bed 1 is badly split up by part-

ings, but they appear to die out to the southeast. Some sections of the bed follow:

Section of bed 1 in S. ½ sec. 31, T. 148 N., R. 89 W.

	Ft.	In.
Lignite		9
Parting		9
Lignite	1	
Parting		6
Lignite	2	6
Total lignite	4	3

Section of bed 1 in NE. ¼ sec. 6, T. 147 N., R. 89 W.

	Ft.	In.
Lignite	2	6
Parting		4
Lignite	2	
Parting		2
Lignite	2	
Total lignite	6	6

In the N. ½ sec. 24, T. 147 N., R. 89 W., bed 1 is about 7 feet thick and free from partings.

Bed 2.—About 125 feet above bed 1, or 200 feet above river level, is another bed which has been traced from a point near Elbowoods eastward to the boundary of the reservation. It has been burned almost continuously along its outcrop, and its thickness was measured in only two places, where it was 4 feet and 6 feet 6 inches thick. To judge by the thickness and persistence of clinker produced by its burning, it is probably a workable bed throughout the distance traced.

Between Missouri River and Sixmile Creek bed 2 lies in a narrow strip with disconnected outliers. From Sixmile Creek eastward to the boundary of the reservation bed 2 is about 125 feet above river level and outcrops at the north edge of the lowland bench, 2 to 4 miles from the Missouri.

In the hills north of Elbowoods no lignite is exposed, but springs and seepages, probably indicating the outcrops of beds, are abundant, especially near the north edge of the lowlands on which the town of Elbowoods is situated.

In the eastern part of T. 148 N., R. 91 W., northwest of Elbowoods, several thin beds of lignite are exposed, but none of them has been observed to exceed 3 feet 8 inches in thickness.

CHARACTER AND USES OF THE LIGNITE.

The lignite on the reservation does not differ in character and composition from that in other parts of the same general region. It is dark brown in color, tough, and woody in structure. The greatest disadvantage encountered in dealing with a lignite is its tendency to slack or [redacted] into small fragments on exposure to the atmosphere. Attempts have been made to overcome this difficulty by briquetting the fuel, but the scheme has not yet come into practical use. When, however, the lignite is not handled much and is kept under shelter away from the action of sunlight and rain it has been known to hold together in good condition through the winter months.

The impurities in the lignite consist mainly of sand and clay partings which are difficult of separation in mining. Intimate mixtures of fine sand or clay and lignite, of irregular shape and extent, are rather common in the beds, and are not easily detected without close examination, as they have the same color as the lignite.

On weathering the lignite, which is usually lusterless and massive, breaks into small, shiny cubical blocks which appear black but give a brown streak or powder.

In the absence of timber lignite is used generally over the region for domestic purposes and is coming into favor as a fuel for various manufacturing industries throughout the State. As most of the inhabitants of the Fort Berthold Reservation live near Missouri River, where timber is plentiful, very little lignite is mined, and that only where conditions are extremely favorable—for example, in places where it can be taken from open pits and it is necessary to remove very little cover to reach the fuel. Timber suitable for mining purposes can be obtained only in the valley of Missouri River.

FUTURE DEVELOPMENT.

Owing to the wide distribution of lignite in this general region it is not likely that any part of the area will develop far in advance of any other part. Some small advantage would arise, of course, should a certain field have extremely favorable conditions as to transportation and thickness and purity of fuel. It seems probable, however, that the lignite will have only a local use for many years to come.

Probably the greatest future use of the lignite will be to generate power for pumping plants to irrigate lands along the larger streams in the State. A number of such projects on Missouri River are now under consideration by the United States Reclamation Service and by the State. One such plant has already been established at Williston. Should these numerous projects be completed great quantities of lignite would be necessary not only for their use, but also to supply settlers attracted by irrigated lands with fuel for domestic purposes, and to supply industries that would probably spring up with an influx of immigration.

North Dakota brown lignite has been tested with great success in the producer-gas plant, as shown by the statement quoted on pages 28–29.

THE FORT PECK INDIAN RESERVATION LIGNITE FIELD, MONTANA.

By Carl D. Smith.

INTRODUCTION.

The Fort Peck Indian Reservation lignite field lies in the northeast corner of Montana, partly in Valley County and partly in Dawson County. (See fig. 1.) Missouri River flows eastward through the field and forms the south boundary of the reservation. The Great Northern Railway follows the valley of the Missouri acrcss the field. At certain seasons of the year the river is navigable, but it is rarely used as a means of transportation.

The investigation on which this paper is based was made in 1908. In the surveyed parts of the field locations were obtained by means of horseback traverses, with frequent ties to established land corners. Where the land has not been surveyed, the main control lines were run by plane-table and buggy-wheel traverses, which were tied to established corners wherever possible and were supplemented by horseback traverses. At the time geologic examinations of the field were being made topographic surveys were in progress on a part of the reservation, but these were not available in the field.

This paper is intended to be entirely of an economic nature, hence little attention is given to matters that do not immediately concern the lignite. As a result of the work of 1908 the mapped area of formations barren of lignite has been extended eastward along Missouri River for a distance of 60 miles.

The writer is deeply indebted to Messrs. J. A. Davis, E. B. Hopkins, and E. L. De Golyer, whose interest and able assistance in the field work have contributed greatly to whatever value this report may have. Mr. De Golyer also rendered able assistance in the office.

TOPOGRAPHY.

The valley of Missouri River divides the field into two distinct topographic provinces. North of the river for a distance of 15 to 20 miles the slopes are as a rule gentle and, with a few exceptions, the valleys are broad with gently sloping sides. Farther north the relief becomes bolder and the large streams are in places bordered by abrupt escarpments and hills ranging in elevation from 200 to 500 feet. The interstream areas are usually broad and flat.

In the north-central part of the reservation, south of Poplar River and Cottonwood Creek, is a gravel-covered terrace about 300 feet above stream level, which slopes gently to the southeast. A remnant of a similar terrace appears in the highlands north of Cottonwood Creek.

South of Missouri River bluffs and hills rise abruptly from the edge of the flood plain to an elevation of several hundred feet. Near the river the topography is rough and in places the country is dissected into badlands, but farther to the south the badlands blend with rolling prairies of low relief.

The entire field considered here lies within the area once covered by the great continental ice sheet, whose effects on the topography are everywhere evident. Preglacial streams have been caused to abandon their channels, which now appear either as broad depressions containing intermittent lakes or as broad valleys occupied by streams of insignificant size. The movement of the glacier over the region has no doubt had a tendency to smooth away preexisting inequalities of the surface, and the retreating ice sheet has left a mantle of drift which has protected underlying formations from the erosion into badland forms common in regions not so protected. South of Missouri River evidences of glaciation are not so marked as they are north of the river.

GEOLOGY.

STRATIGRAPHY.

The following table gives a summary of the formations occurring in this field:

Stratigraphy of the Fort Peck Indian Reservation lignite field, Montana.

System.	Formation.	Thickness.	Description.
		Feet.	
Quaternary			Alluvium.
			Glacial drift.
Tertiary	Fort Union formation	1,000+	Yellowish sands and sandstones interbedded with gray clays and lignite.
(?)		200	Somber-colored sands and clays with numerous carbonaceous layers and a few lignite beds.
Cretaceous (?)	Fox Hills (?) sandstone	200	Buff-colored soft sandstones interstratified with some gray clay.
Cretaceous	Pierre shale	1,000+	Dark-gray shale, in places brown. Very soft and friable.

PIERRE SHALE.

The basal member of the rock section occurring in the Fort Peck field is a dark-gray shale, in places brown, which is as a whole very soft and friable, but contains at irregular intervals thin layers of limy material. Near the top of the formation appear many bowlder-like limy concretions, 1 to 2 feet in diameter, some of which are made up almost wholly of fossil shells. Others contain no fossils and many are intersected by a network of calcite veins which are usually of a lighter color than the matrix.

According to T. W. Stanton fossils collected from this formation are very distinctive. "In fact, they are characteristic of a horizon in the upper Pierre corresponding to the shale above the Judith River formation which farther west in Montana has been called the Bearpaw shale."

As indicated on the accompanying map (Pl. III) the Pierre shale covers the greater part of the west end of the field and extends eastward in an area of varying width along Missouri River nearly to the town of Brockton, on the Great Northern Railway. The base of the shale does not appear in the Fort Peck field, but there is reason to believe that it is more than 1,000 feet thick, as at least that thickness occurs in this field. The Pierre shale is barren of coal, and so far as known carries no other economic product, with the possible exception of clay for brickmaking. As the shale contains no ledge-making material bluffs are rare in the area which it underlies as the surface rock. Streams whose courses lie in the shale are usually more alkaline than those elsewhere.

FOX HILLS (?) SANDSTONE.

Conformably overlying the Pierre shale is a series about 200 feet thick consisting of buff sandstones interstratified with some gray clay. As a rule the sandstone is soft, but in places it appears as hard concretion-like masses which stand out as ledges in the process of weathering or as masses of cannon-ball shape embedded in a matrix of softer rock. The material shows great irregularity of bedding, is extremely variable in character horizontally, and is in places cross-bedded and conglomeratic.

The age of these beds is doubtful. They occupy a position in the section which to the south and southeast is occupied by the Fox Hills sandstone, but no fossils could be found in the beds; hence further work in the region will be necessary to determine their age. For the present they are called Fox Hills (?) sandstone. Like the Pierre shale these buff beds are barren of coal. Excellent exposures of this formation can be seen in the part of the field south of Missouri River, especially in the high river bluff south of Brockton. North of the river glacial drift so conceals the formation that good exposures can be seen at only a few places. These are near the head of Cottonwood Creek in the northern part of the reservation, and on Wolf Creek near the town of Wolf Point.

SOMBER-COLORED BEDS.

About 200 feet of somber-colored sands and clays, with numerous carbonaceous layers and a few beds of impure lignite, overlie the Fox Hills (?) sandstone and are also of doubtful age. They are regarded by F. H. Knowlton as having very strong Fort Union (early Eocene) affinities. In the field covered by this report there is no apparent unconformity between the Fox Hills (?) sandstone and the somber-colored beds. Although the upper part of the somber-colored beds differs from the lower part of the Fox Hills (?) sandstone in character of constituent materials the two formations so grade into each other that their contact is very indefinite. At some places the somber-colored beds contain irregular masses of hard sandstone and thin beds of impure limestone. In weathering this hard material stands out as ledges or serves as protecting caps for pedestals of softer sands or clays. Excellent exposures of the somber-colored beds can be seen in the badlands south of Missouri River, on Cottonwood Creek, and Poplar River in the Fort Peck Indian Reservation. Because of the uncertainty of the position of the contact of the Fox Hills (?) sandstone and the somber-colored beds north of Missouri River they have been grouped together in mapping.

FORT UNION FORMATION.

The uppermost formation in the Fort Peck region is made up of yellowish sands and sandstones interbedded with gray clays and lignite, the sands and sandstones predominating. One thousand feet or more of this formation, which appears to represent more stable conditions of deposition than the Fox Hills (?) sandstone and the somber-colored beds below, is exposed in the field. As a whole this formation has a yellowish hue. According to F. H. Knowlton the beds are Fort Union in age. Their contact with the somber-colored beds below is usually well marked by an abrupt change in color and character of material. Lignite occurs abundantly in these yellow beds, and is much more constant in quality and horizontal distribution than the lignite of the somber-colored beds. Excellent exposures of the yellow Fort Union formation can be seen east of Brockton both north and south of the river, in the northeastern part of the reservation, and in the escarpments bordering the valley of Poplar River.

GLACIAL DRIFT.

Overlying the greater part of the field is a mantle of glacial material of varying thickness, made up principally of igneous bowlders and clay, but containing some fossiliferous limestones. These bowlders vary in size from mere pebbles to masses weighing probably 20 tons. It is probable that this drift formerly covered the entire region like a huge blanket, but stream action and weathering agencies subsequent to the retreat of the continental ice sheet have cut deep channels through the drift and into underlying formations. It may be readily seen that isolated exposures of the underlying rock not concealed by glacial drift are rather difficult of correlation, and this difficulty is augmented by the variability of the lignite-bearing formations.

STRUCTURE.

As originally deposited the strata which make up the rock section in and near the Fort Peck Indian Reservation were approximately horizontal, but since their deposition some force has so tilted them that they now dip gently toward the east. This dip, however, is not constant in direction nor degree. A low dome, near the center of which Poplar is located, breaks the continuity of the dip, and causes a slight reverse dip to the west, thus producing a shallow syncline pitching southeastward whose axis trends northwest and southeast a few miles east of Wolf Point. The formations immediately concerned in the Poplar dome dip away from it in every direction, the direction of the dip at any particular point being determined by the direction of such a point of observation from the center of the dome. Thus the formations at a point due east of the center dip to the east. The lignite beds along the river east of Brockton dip eastward at about 100 to 135 feet to the mile. In directions other than east of the dome, where its presence only intensifies the general dip, its effect does not reach beyond 15 miles.

THE LIGNITE.

GENERAL DESCRIPTION.

By reference to the sections given on the following pages it will be noted that many lignite beds occur in this field. Relatively few of these beds, however, are of sufficient thickness for consideration as mining possibilities. Wherever wide areas are concealed between the districts discussed no attempt has been made to correlate individual beds from one to another.

The character of the materials that inclose lignite beds is so changeable that it is never possible to predict what the roof and floor of any particular bed are likely to be a few yards from the point of actual exposure. As a general rule it may be said that a few feet of the lignite bed itself, should its thickness permit, will make a much stronger roof than any material that may overlie it. Timber suitable for mine purposes is very scarce except in the valley of Missouri River. Water, while not abundant except in the rivers, could be stored by building reservoirs in small streams and could possibly be obtained from wells.

The lignite beds which occur in the somber-colored formation have shown so much variability in quality, thickness, and lateral extent that, in the presence of better lignite in the Fort Union formation, they are considered worthless as a whole. In places they have a workable thickness and have been burned along their outcrops, but on account of their uncertainty of character no attempt was made to note them closely.

Lignite beds of workable thickness and purity occur at intervals through the entire thickness of the Fort Union formation exposed in the field. They are much more constant in character than those occurring in the somber-colored beds, and are here treated more in detail. Near Missouri River the outcrops of the principal beds have been traced and mapped, but away from the river no attempt has been made to follow out individual beds.

A feature of the region, especially noticeable south of Missouri River, is the clinker produced by the burning of lignite beds along their outcrops. This material, which is usually red, is an unfailing index to the position of the bed burned. It would, in many localities, be extremely difficult to meander outcrops of beds without the clinker as a guide. To some extent also the persistence and thickness of the clinker give some idea of the persistence, quality, and thickness of the burnt bed, as thick beds of good quality produce a greater thickness and more completely fused zones of clinker than thin or impure beds. The distance back from the outcrop of a bed to which burning may take place is governed by the thickness of cover, which, if great enough, smothers the fire by preventing access of air. In this connection it is impossible to give exact figures, as no mining or prospecting has been done where it was necessary to remove the clinker to reach the lignite. To the observer, however, the width of the clinkered zone is often an obvious matter. In prospecting for lignite on an outcrop that has been burned it may be well to keep in mind the fact that the base of the clinker, which is usually well marked, is on a level with the base of the burnt bed of lignite.

The areal distribution of the formations that occur in this field is shown on Plate III. The principal wagon roads are shown, except those in the valley of Missouri River, where there is such a network of roads that to represent them would only complicate the map. The outcrops of important beds of lignite in the eastern part of the field are also shown on the map. In the field no attempt was made to map the contact of the river alluvium with older formations. The map is compiled from Missouri River Commission maps and township plats of the General Land Office. The Fort Peck Indian Reservation constitutes the greater part of the field. The north boundary of the reservation is the north boundary of the area mapped. On the west the reservation is bounded by Porcupine Creek, on the south by Missouri River, and on the east by Big Muddy Creek.

DISTRIBUTION OF LIGNITE.

For convenience of description the field is divided into more or less arbitrary districts. The districts nearest the Great Northern Railway and Missouri River, on account of their accessibility, have been examined in greater detail than those more remote from lines of transportation.

BROCKTON-CULBERTSON DISTRICT.

The Brockton-Culbertson district includes the region in the reservation east of Brockton, between Missouri River and the seventh standard parallel, and a small area about Culbertson east of Big Muddy Creek. This district, because of its accessibility, has been studied in more detail than other parts of the field, especially in T. 28 N., Rs. 53 and 54 E., where the two important lignite beds have been followed in their outcrops by means of stadia measurements and where concealed have been prospected by means of a hand drill.

The dip of the lignite beds and containing formations in this district is to the east, its amount ranging from 25 to 135 feet to the mile. A section compiled from scattered exposures and supplemented by observations made south of Missouri River, with unimportant lignite beds eliminated, is given below. For convenience of description, the important beds are designated by letters A, B, C, etc., A corresponding to the lowest workable bed.

Section in Brockton-Culbertson district.

	Ft.	in.
Lignite (bed G)	9	
Clay and sand	90	
Lignite	4-6	
Clay	10-27	
Lignite (bed F)	5	6
Sand and clay	70	
Lignite (bed E)	3-6	
Sand and clay	130	
Lignite	5	7
Clay	6	
Lignite (bed D)	9	
Sand and clay	95	
Lignite (bed C)	2	
Sand and clay	115	
Lignite (bed B)	1-5	6
Sand and clay	275	
Lignite	5	
Clay	15	
Lignite (bed A)	7	7
	884	2

From the above section it may be noted that about 900 feet of strata bearing workable beds of lignite are exposed in the Brockton-Culbertson district.

Only three beds of lignite occurring in this district east of Big Muddy Creek are of sufficient thickness to warrant consideration. On the map these are termed beds F and G, F being made to include the two lower beds, which are so close together in the section that their mapped outcrops practically coincide. The outcrops of these beds are shown on the map (Pl. III). The prevailing eastward dip of the beds is so much less about Culbertson as to be practically negligible so far as its effects on mining is concerned.

Bed A.—In T. 28 N., R. 53 E., bed A lies at the contact of the somber-colored beds with the Fort Union formation above. Another bed appears a few feet above bed A, and it is possible that in attempting to map the outcrop of bed A locations were at some places taken on the upper bed, but they are so near in the geologic section that their outcrops practically coincide.

The outcrop of bed A is shown on Plate III. From the point where Box Elder Creek flows out of the hills into river alluvium the bed rises gradually northwestward to the top of the divide between the river and Lake Creek. From the top of the divide the outcrop of the bed was followed in a northeast course to the seventh standard parallel. The bed dips to the east about 100 feet to the mile and presumably underlies all the territory east of its mapped outcrop. In secs. 21 and 22 bed A has been burned along its outcrop, producing a considerable amount of red clinker. A section of bed A in the NE. ¼ sec. 21, T. 28 N., R. 53 E., shows 6 feet 5 inches of lignite, with sandstone roof and clay floor.

Near the middle of sec. 21, T. 28 N., R. 53 E., bed A is exposed naturally in the point of a hill, where the following section was measured:

Section of bed A near middle of sec. 21, T. 28 N., R. 53 E.

	Ft.	In.
Clay roof.		
Lignite	2	2
Clay		1
Lignite	2	7
Lignite, dirty		4
Lignite	2	6
Total lignite	7	7

A hole drilled in the NE. ¼ sec. 8 revealed only 4 feet 8 inches of lignite. It is probable that the lignite struck here is the smaller upper bed which lies about 10 feet above bed A.

An exposure of the small bed above bed A was seen in the SE. ¼ sec. 22 near the wagon road, just east of Box Elder Creek. A section follows:

Section of lignite bed in SE. ¼ sec. 22, T. 28 N., R. 53 E.

	Ft.	In.
Sandy clay roof.		
Lignite	1	6
Clay	1	
Lignite	3	6
Total lignite	5	

Several attempts were made to reach bed A at points along its outcrop, but it is so concealed by glacial drift that no satisfactory results could be obtained. Bed A wherever measured contains some thin partings, but they are not of sufficient thickness to interfere seriously with mining operations. No attempt was made to follow the outcrop of this bed north of the seventh standard parallel.

Accessible parts of the outcrop of bed A are probably too far from the river to utilize that stream as a source of water for mining purposes, but a reservoir could be formed by damming Box Elder Creek. In case no great amount of water should be needed, it might be obtained from wells, possibly artesian.

Bed B.—In secs. 30 and 31, T. 28 N., R. 54 E., just north of the Great Northern Railway, is a small area of badlands in which bed B is well exposed. It is 300 feet higher in the rock section than bed A, and, like the beds above and below it, rises gradually to the west. Many exposures of the bed were measured, but it shows so much variability in thickness that it is not considered of much value. Its greatest measured thickness is 5 feet 6 inches and its least 1 foot. It is usually very impure.

Bed C.—In the Brockton-Culbertson district bed C is about 2 feet thick and is of little consequence. It is included here principally because it is thicker on the south side of the river. It is about 115 feet above bed B in the rock section, and was measured in only one place, in the western part of T. 28 N., R. 54 E.

Bed D.—For about 500 feet in the section above bed A many thin beds of lignite occur, but none of them has shown workable thickness in the Brockton-Culbertson district. The outcrop of bed D is similar to that of bed A in that it swings to the northwest from the edge of the river alluvium to the top of the divide between the river and Lake Creek, thence northeastward to the seventh standard parallel, beyond which its outcrop was not followed. The outcrop lies almost wholly in T. 28 N., R. 54 E., and the dip of the bed to the east in the western part of the township is about 135 feet to the mile, somewhat more than the dip of bed A. It presumably underlies all the territory east of its outcrop.

East of the point where the outcrop of bed D is concealed by river alluvium there is probably a diminution in the amount of dip. In other words, from sec. 26 eastward to Big Muddy Creek bed D probably lies almost flat, but is still inclined slightly to the east.

Westward from the middle of sec. 20 bed D has been burned for a short distance along its outcrop. Near the middle of sec. 20 a hole was drilled which revealed the following section:

Section of lignite in drill hole in sec. 20, T. 28 N., R. 54 E.

	Ft.	In.
Clay roof.		
Lignite	5	7
Clay, sandy	6	
Lignite (bed D)	9	
Total lignite	14	7

Another hole was drilled through bed D near the middle of sec. 4, and revealed 8 feet 8 inches of lignite.

A bed of lignite 5 feet 7 inches thick overlies bed D, from which it is separated by 6 feet of clay. These beds are so near that the general conditions affecting one also apply to the other.

Bed E.—No exposure of bed E was seen in the Brockton-Culbertson district. The thickness given in the general section was measured on the south side of Missouri River, where the bed is well exposed and lies about 140 feet stratigraphically above bed D.

Bed F.—It will be seen by reference to the map (Pl. III) that bed F underlies considerable territory in T. 28 N., Rs. 55 and 56 E. Its outcrop follows closely the base of the hills bordering the flood plains of Big Muddy Creek and Missouri River, and in elevation it is about 100 feet above the Missouri. Above bed F and separated from it by 10 to 27 feet is another bed which in places reaches workable thickness.

Section of bed F near quarter corner between secs. 5 and 6, T. 28 N., R. 55 E.

	Feet.
Lignite	6
Clay and sand	27
Lignite (bed F)	4+
Total lignite	10+

In this section the base of bed F is concealed. Two exposures about 1½ miles farther northwest showed 6 to 8 feet of lignite, free from partings.

Section of bed F in SW. ¼ sec. 26, T. 28 N., R. 55 E.

	Ft.	In.
Lignite	3	8
Clay and sand	17	
Lignite (bed F)	5	
Total lignite	8	8

Where the bed is not covered by hill wash it is in many places so fringed by clinker that no satisfactory measurements could be made. Both benches of bed F are free from partings and appear to be of excellent quality.

Bed G.—A part of the outcrop of bed G, 115 feet above bed F or 215 feet above Missouri River level, has been mapped near Culbertson. The thickness of the bed was measured in only one place, at the Bruegger mine, 3 miles north of Culbertson, a description of which follows. This bed has been burned somewhat along its outcrop. Its exploitation is considered a safe mining venture, but it is rather inaccessible on account of its elevation and distance from means of transportation.

About 3 miles north of Culbertson the Bruegger mine has been opened on bed G. The main entry runs north and is about 200 feet in length. The bed is 8 feet 6 inches to 9 feet thick, is free from partings, and is of good quality, as shown by the analysis on page 55. The fuel is hauled by wagons to Culbertson for local use.

DISTRICT SOUTH OF MISSOURI RIVER.

The district described here is bounded on the north by Missouri River, on the west by the tenth guide meridian, and on the south by the sixth standard parallel, and extends eastward to a point south of Missouri River opposite Culbertson.

In structure it is similar to the region north of the river. The general dip is to the east or a little south of east, with a slight reverse dip to the west from Redwater River westward for 15 miles. This reverse dip is due to the shallow, southeastward-pitching syncline mentioned above as lying between the Poplar dome and Wolf Point. The effect of this syncline is to bring the lower contact of the Fort Union beds, the principal lignite-bearing formation, to a lower level and therefore nearer the river. Westward from the mouth of Swartz Creek, opposite Wolf Point, the beds rise gradually, thus throwing the Fort Union lignite-bearing formation farther from Missouri River.

The contact of the somber-colored beds with the overlying Fort Union formation, at or above which the better beds of lignite occur, is shown on the map (Pl. III). The lignite which occurs near this horizon, west of Charlie Creek, because of its general inaccessibility in that direction, has not been measured or mapped with as much accuracy as the beds east of Charlie Creek. Workable beds near the river west of Charlie Creek occur as irregular outliers with thin cover, 400 feet or more above the river bottoms. In the southern part of T. 27 N., R. 49 E., a 5-foot bed of lignite occurs in the somber-colored beds and it has been mined to some extent on Nickwall Creek for use at Poplar.

The eastward dip whose effect begins to be felt strongly 10 miles east of Redwater River brings the base of the Fort Union, the principal lignite-bearing formation, down to river level near the mouth of Charlie Creek, eastward from which lignite beds successively higher in the section appear near river level.

East of the mouth of Charlie Creek lignite beds occur in abundance and have practically the same distribution stratigraphically as in the Brockton-Culbertson district. For convenience of description the important beds are designated by letters, similar letters being given to beds correlated as the same in the two districts.

Bed A.—The bed of lignite which occurs at the contact of the Fort Union formation and the somber-colored beds in the Brockton-Culbertson district appears south of the river in T. 27 N., R. 53 E., near Charlie Creek. The bed dips to the east about 100 feet to the mile and disappears below the level of Missouri River a short distance east of the mouth of Charlie Creek. Near the river the outcrop of bed A is so concealed that only a partial exposure could be seen. This was near West Charlie Creek, in the southern part of T. 27 N., R. 53 E. A section follows:

Section of bed A on West Charlie Creek.

Sand roof.	Ft.	In.
Lignite		2
Parting		2
Lignite	1	6
Parting		1
Lignite	1	5
Parting		1
Lignite	2	9
Parting		2
Lignite (base concealed)		7
Total lignite exposed	6	5

East of the mouth of Charlie Creek the outcrop of bed A should be found near the river, but its character and thickness there are not known.

Bed B.—South of Missouri River bed B could not be recognized. Its outcrop should lie between the mouth of Charlie Creek and Balls Bluff to the east, but from its character north of the river it is not surprising that the bed should have pinched out here.

East of the mouth of Charlie Creek the outcrops of the principal lignite beds have been followed only near the river, where they are well exposed in the bluffs and badlands.

Bed C.—In Balls Bluff, just south of Missouri River in the north-central part of T. 27 N., R. 54 E., bed C is well exposed and averages 4 to 5 feet in thickness. Here the bed is about 150 feet above the river, but near the east line of the township the eastward dip of the bed carries it below river level. Westward from Balls Bluff the outcrop of bed C rises rapidly and swings to the south, where it could not be followed because of the smooth, grass-covered character of the country.

Bed D.—In outcrop bed D closely follows bed C, from which it is separated by 50 to 100 feet of sandy clay, but on account of the diminution of the dip to the east it extends down Missouri River nearly to the mouth of Twomile Creek before disappearing. Bed D averages nearly 10 feet in thickness and has in places a few partings that are too thin to interfere with mining. Some detailed measurements of bed D follow:

Section of bed D in eastern part of T. 27 N., R. 54 E.

Sandy clay roof.	Ft.	in.
Lignite	6	6
Clay		3
Lignite	2	10
Sand		2
Lignite		6
Total lignite	9	10

Section of bed D at Balls Bluff in north-central part of T. 27 N., R. 54 E.

Soft sandstone roof.	Ft.	in.
Lignite, dirty	1	
Lignite	6	6
Clay		2
Lignite	2	6
Total lignite	10	

At a number of points along their outcrops beds C and D are well located with reference to transportation by water, and are easily accessible to mining for domestic purposes.

Beds E, F, and G.—In T. 27 N., R. 54 E., and between Twomile and Hardscrabble creeks, beds E and F appear as narrow outliers capping the highest divides. Their outcrops are nearly everywhere fringed by clinker, making frequent measurements of their thickness impossible by the usual means. Near the east line of T. 27 N., R. 54 E., the eastward dip of the beds is about 100 feet to the mile, but farther east the dip diminishes considerably, probably not amounting to more than 25 feet to the mile opposite Culbertson.

A section of bed E in the northeast-central part of T. 27 N., R. 54 E., shows 8 feet 8 inches of good lignite. To the east the bed diminishes considerably in thickness. In the SW. ¼ sec. 11, T. 27 N., R. 55 E., it is about 4 feet thick, with a thin parting near the base. A measurement of bed E in the N. ½ sec. 8, T. 27 N., R. 56 E., in the south bank of Missouri River opposite Culbertson, shows 4 feet 9 inches of lignite, with three thin partings. East of Hardscrabble

Creek bed F occurs near the top of the bluff bordering the river flat and is burnt continuously along its outcrop. The bed lies about 150 feet above river level near the mouth of Hardscrabble Creek and 100 feet above river level at the ferry south of Culbertson. The dip of the bed to the east is probably not more than 25 feet to the mile, hence so far as mining is concerned it may be regarded as lying flat.

About half a mile west of the ferry south of Culbertson, where the wagon road crosses the point of a hill, 8 feet 6 inches of bed F was measured, the base being concealed. It is here free from partings and appears to be of excellent quality.

Section of bed F in NW. ¼ sec. 9, T. 27 N., R. 56 E.

	Ft.	In.
Sandstone roof.		
Lignite	4	
Clay and sandy clay	15	
Lignite (bed F)	6	6
Total lignite	10	6

One-fourth mile east of this locality a mine has been opened on bed F. A section follows:

Section of bed F in sec. 9, T. 27 N., R. 56 E.

	Ft.	In.
Clay roof.		
Lignite	3	11
Clay		2
Lignite	3	9
Clay		1
Lignite	1	10
Total lignite	9	6

The great thickness of clinker attending bed F is probably due to the combustion of this bed together with the 4-foot bed 15 to 20 feet above.

Bed F, though not ideally situated with reference to water transportation, is at many places near enough to the river to be reached by an incline from the edge of the water. The quality of the bed is everywhere apparently good.

The outcrop of bed G was not traced south of Missouri River. About 2 miles south of Culbertson ferry this bed is exposed and measures 5 feet 6 inches of clean lignite.

NORTHEAST CORNER OF RESERVATION.

No attempt has been made to trace individual beds of lignite in the northeast corner of the reservation, as the region is so covered by glacial material as to make close correlations impossible. As in other parts of the field the contact of the somber-colored beds with the Fort Union formation above marks practically the lower limit of workable lignite. Above this contact the distribution of lignite beds is probably not radically different from their distribution in the Brockton-Culbertson district, except that beds higher in the stratigraphic section appear. The general dip of the strata is to the east, possibly a little south of east, in amount ranging from a few feet to 100 feet to the mile.

Lignite on Smoke Creek.—Lignite is exposed at many places on Smoke Creek near water level. In all probability these exposures are on the same bed, whose dip to the southeast is practically the same as the fall of the creek. At no place could the full thickness be seen. Near West's ranch the bed has been mined for local use. Some sections follow:

Section about 4 miles up Smoke Creek from West's ranch.

	Ft.	In.
Lignite	2	5
Parting		1
Lignite (base concealed)	4	2

Section in north bank of Smoke Creek at West's ranch.

	Ft.	In.
Lignite	2	5
Parting		1
Lignite (base concealed)	4	2

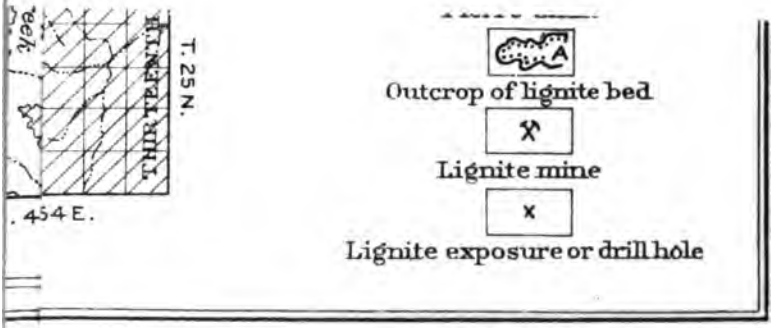
Section about 6½ miles down Smoke Creek from West's ranch.

	Ft.	In.
Lignite	2	5
Parting		1
Lignite (base concealed)	5	6

In the bluff south of West's ranch a number of lignite beds appear, two of which have been burned along their outcrops and may be of workable thickness. These are 140 and 160 feet above the level of Smoke Creek.

Lignite on Sauerkraut Creek.—A bed of lignite 5 feet 10 inches thick is exposed on Sauerkraut Creek, a small stream that flows southeastward between Smoke and Wolf creeks. About 2½ miles southwest of Scott's ranch on Wolf Creek the lignite has been mined for local use. The bed appears to dip slightly to the southeast and is overlain by sandstone. Other exposures of thin beds of lignite were noted on Sauerkraut Creek.

Lignite near Wolf Creek.—Near the heads of small streams which enter Wolf Creek from the west the country is cut into badlands, exposing several beds of lignite. These beds have been considerably burned in their outcrops, forming a red clinker. A measurement of the thickest bed gave 6 feet of lignite, with a 4-inch parting 1 foot from the top.



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A section of the rocks exposed at the head of a small stream entering Wolf Creek from the west 6 miles upstream from Scott's ranch follows:

Section of beds west of Wolf Creek.

	Ft.	in.
Sands and clays, yellowish	150	
Sand, blue and yellow	20	
Clay, carbonaceous		6
Sandstone, yellow	12	
Clay, some lignite	9	
Sand and clay	15	
Clay, carbonaceous	2	
Clay, sandy	21	
Sand	10	
Lignite		8
Clay	10	
Clay, sandy	17	
Lignite		8
Clay	4	
Lignite	1	
Clay	8	
Sand, yellow	16	
Clay and sand	15	
Lignite		3
Sand	6	
Lignite	6	
Clay and sand	15	
Lignite	2	
Sand and clay	60	
Level of Wolf Creek.		
	401	1

Very little lignite shows in the drainage basin of Wolf Creek, except as noted in the foregoing section, about 75 feet above the level of the stream, although a section of rocks 500 feet or more thick is well exposed in the region.

On the east side of Wolf Creek, 15 miles above Scott's ranch a 5-foot bed was seen. This bed was on fire near the point where it was measured.

Other localities.—On Otter Creek, a small tributary of Big Muddy Creek in the extreme northeast corner of the reservation, a bed of lignite outcrops but has been so completely burned that no satisfactory measurements could be made.

In the west bank of Big Muddy Creek 3 miles northeast of Scott's ranch several thin beds of lignite were noted, but they were not of sufficient thickness to warrant much attention.

From Kern's ranch, on Poplar River, about 9 miles north of the seventh standard parallel, northwestward to the north boundary of the reservation, the contact of the somber-colored beds with the overlying Fort Union formation is easily traceable and is usually marked by the presence of several beds of lignite, both above and below. From Kern's ranch southeastward to the seventh standard parallel the lower contact of the Fort Union is so generally concealed that its position is indefinite.

On Hay Creek, 3 miles north of Kern's ranch, lignite has been mined for local use. At the time the mine was examined only 3 feet 7 inches of the bed was exposed, the base being concealed. A thin parting occurs near the top of the bed.

The area in the northeast corner of the reservation underlain by the Fort Union formation is shown on the map accompanying this report. Although in this area lignite is exposed only along the large streams it is probable that prospecting elsewhere would reveal many workable beds now concealed by débris.

NORTH-CENTRAL PART OF RESERVATION.

In the north-central part of the reservation, south of West Branch of Poplar River and Cottonwood Creek, is a high plateau whose north boundary is marked by an abrupt escarpment in which the contact of the somber-colored beds with the Fort Union formation above is exposed. This contact, at or near which several beds of lignite usually occur, is about 200 feet above the level of Poplar River. The land between the base of the escarpment and Poplar River has a uniform slope, but is in places deeply trenched by short northward-flowing streams. The highest part of the plateau lies next to its north boundary, from which the slope is gentle to the south for several miles, to a region where streams heading in the plateau gain sufficient strength to cut deep valleys, thus changing the character of the country from a smooth to a rolling prairie with gulches here and there.

The lower contact of the prolifically lignite-bearing formation on the south side of the plateau could not be located with certainty because of the smooth, grass-covered character of the country. The contact of the somber-colored beds and Fort Union formation in this plateau rises gradually to the west to a point a few miles east of the head of Cottonwood Creek, where it is intercepted by a gravel terrace the grade of which, although in the same direction, is slightly less than the rise of the contact.

Section at high white point at east end of plateau south of West Branch of Poplar River.

	Ft.	in.
Sandstone, soft, yellowish	40	
Lignite		5
Clay	1	9
Lignite		7
Clay	2	3
Lignite	6	

	Ft.	In.
Clay and sand, somber	77	
Lignite	4	5
Clay, carbonaceous	2	8
Lignite	1	
Clay, gray	3	
Sandstone, gray	17	5
Lignite	2	1
Clay, carbonaceous	2	3
Sand, clayey	20	
	180	10

Section in badlands southeast of junction of Cottonwood Creek and West Branch of Poplar River.

	Ft.	In.
Gravel	15	
Sandstone, coarse, white	2	6
Sandstone, yellowish, and gray clay	40	
Lignite		5
Clay		6
Lignite	3	
Sand, clayey	20	
Sandstone, soft	10	
Lignite	1	
Sandstone, clayey	15	
Clay, dark gray	40	
Lignite	3	6
Clay	1	6
Lignite	5	
Clay, sandy	4	
Lignite	6	6
Clay	5	
Sand	10	
Clay, sandy, with two thin beds of lignite at top	17	6
Lignite	1	
Clay	12	6
Sandstone, cream-colored	5	
Lignite	2	
Clay	3	
Sand, somber	15	
Lignite	3	9
Clay, sandy, somber.		
	242	8

As shown by the sections, a number of lignite beds occur in this area, but they are rather inaccessible because of their elevation. Water for mining purposes is scarce or lacking altogether.

Section of somber-colored beds in badlands southeast of Kern's ranch.

	Ft.	In.
Sand and clay	12	
Lignite, bony	2	6
Sand, yellow	6	
Lignite, thin		
Sand	2	6
Lignite		8
Sand and clay	10	
Lignite	1	3
Clay and sand	47	6
Lignite	2	
Clay	10	
Lignite	1	
Sand	10	
Lignite, thin		
Clay and sand	28	6
Lignite		8
Sand and clay	65	
Lignite, thin		
Clay	17	
Lignite	1	
Clay, with two thin seams lignite	24	
	241	7

North of Cottonwood Creek and between East and West branches of Poplar River are some small areas underlain by yellow beds of the Fort Union formation, but they are similar to the plateau just described so far as general conditions of accessibility are concerned and will not be discussed further. Their extent is shown on Plate III.

Section of lignite beds in NE. ¼ sec. 6, T. 28 N., R. 47 E.

	Ft.	In.
Gravel and clay	15	
Sand	5	
Clay, sandy	8	
Lignite	1	10
Clay	8	
Lignite	1	10
Clay, sandy	20	
Lignite	1	8
Clay		5
Lignite	1	
	62	9

The lignite beds noted in the foregoing section appear in a high point of land which is crossed by the seventh standard parallel just east of Wolf Creek. A short distance northeast of the point where the section was made one of the beds noted has been mined for local use. About 40 acres of surveyed land is underlain by the lignite.

CHARACTER AND USES OF THE LIGNITE.

The lignite in the Fort Peck field does not differ in character and composition from that in other parts of the same general region. It is dark brown in color, tough, and woody in structure.

The following analysis represents a sample of lignite obtained 3 miles north of Culbertson, which is the only place near the reservation where an unweathered sample could be obtained at the time, but it is thought that fuel in other parts of the field will not differ materially in quality from this sample. The analysis was made at the laboratory of the United States Geological Survey fuel-testing plant, Pittsburg, Pa.

Proximate analysis and calorific determinations of lignite from the Bruegger mine, 3 miles north of Culbertson, Mont.

[F. M. Stanton, chemist in charge.]

Laboratory No.	7050	Loss of moisture on air-drying	38.70
Sample as received:		Air-dried sample:	
Moisture	43.16	Moisture	7.28
Volatile matter	22.03	Volatile matter	35.93
Fixed carbon	28.99	Fixed carbon	47.29
Ash	5.82	Ash	9.50
Sulphur	.29	Sulphur	.48
Calories	3,333	Calories	5,437
British thermal units	5,999	British thermal units	9,787

This sample was taken according to Survey regulations and represents the whole thickness of the bed. After crushing, the lignite was sealed in a galvanized can and thus reached the laboratory in practically the same condition as it was in the mine. As shown by the analysis the sample as received at the laboratory contained 43.16 per cent of moisture, which is somewhat high even for a lignite. It is probable that the analysis of the air-dried sample represents approximately the condition of the fuel as it would reach the consumer, for much of its moisture is lost through handling.

In the absence of timber, which is almost totally lacking in this region except in the river valleys, lignite is used generally for domestic purposes. However, as most of the inhabitants of the Fort Peck region live near Missouri River, where timber is comparatively plentiful, little lignite is mined. Except at the Bruegger mine it is taken from open pits where it is necessary to remove only a small amount of overburden.

FUTURE DEVELOPMENT.

Lignite is widely distributed in this general region and it is not likely that any part of the area will develop far in advance of any other part, though if a certain field should have extremely favorable conditions of transportation, thickness, and purity of fuel it would derive some advantage therefrom. It seems probable, therefore, that the fuel will have only a local use for many years to come and that it will not enter seriously into competition outside of its own territory with better grades of fuel mined in other parts of Montana.

Probably the greatest future use of the lignite will be in generating power for pumping plants to irrigate lands where gravity systems are impracticable, but lands however irrigated would attract many settlers, thus creating a great demand for fuel for domestic purposes.

THE CENTRAL PART OF THE BULL MOUNTAIN COAL FIELD, MONTANA.[a]

By R. W. Richards.

INTRODUCTION.

Field work.—The survey of the Bull Mountain coal field, Montana, which was begun during the summer of 1907 by L. H. Woolsey,[b] was continued during the month of May and up to the middle of June, 1908, by M. A. Pishel and the writer, and from that time until the 1st of November by Henry Hinds, Frank R. Clark, James H. Bridges, and the writer. The present paper is a preliminary statement of the results obtained in the area bordering the north and east sides of that portion of the Bull Mountain field examined and discussed by Woolsey. The residents of the region rendered valuable assistance and the Republic Coal Company materially aided the progress of the work by the contribution of information gathered by its prospecting parties.

The primary purpose of the survey, as in the previous season, was the collecting of data for the classification and valuation of public lands supposed to be coal bearing. The only investigation in the Bull Mountain coal field previous to that of 1907 was that of the geologists of the Transcontinental Survey in 1881.[c] This was largely confined to the Mammoth coal bed, the discussion of which has been reviewed by Woolsey. The results of this earlier work, so far as identification is possible, agree closely with those obtained by the Geological Survey, but the work itself was carried on with much less detail.

Location and extent.—The Bull Mountain coal field is located in the southeast-central part of Montana, as may be seen by referring to the index maps of Plates IV and V. The field lies, roughly speaking, about 30 miles north of Billings, and is mainly bounded on the north by Musselshell River. Two parts of the field, however, cross the river, one in the vicinity of Musselshell and the other near Roundup. The east boundary of the field is still more irregular and crosses the heads of Wild Horse and Alkali creeks about 12 miles east of Musselshell post-office, in R. 31 E. The south boundary is within T. 5 N.

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[a] A full report on this coal field is in preparation and will be published as a separate bulletin.

[b] Woolsey, L. H., The Bull Mountain coal field, Montana: Bull. U. S. Geol. Survey No. 341, 1908, pp. 62-77.

[c] Eldridge, G. H., Montana coal fields: Tenth Census, vol. 15, 1886, pp. 753-755.

The field as a whole is about 36 miles from north to south and 30 miles from east to west. The part treated in this report is L-shaped and comprises about 612 square miles. It includes Ts. 5 and 6 N., Rs. 28 and 29 E.; T. 7 N., Rs. 25, 26, 27, 28, and 29 E.; T. 8 N., Rs. 25, 26, 27, 28, 29, and 30 E.; and portions of T. 9 N., Rs. 27 and 28 E. Roundup, the only mining town of the field, and the center of population, is situated on Musselshell River in T. 8 N., R. 25 E., about 2 miles northeast of a small trading point, formerly known as Roundup post-office. It presents to-day a remarkable instance of the rapid growth of a coal-mining camp.

Commercial relations.—The Bull Mountain coal field has been brought into prominence by the building of the Pacific coast extension of the Chicago, Milwaukee and St. Paul Railway, now known as the Chicago, Milwaukee and Puget Sound Railway. This field is the most promising source of coal supply for this new transcontinental road, a fact which has led to its rapid development.

Butte, a mining and smelting center, and one of the largest consumers of coal in Montana, is entered by the line of railway passing through Bull Mountain, and Roundup coal is being brought into this market on favorable competitive terms with coal from the other fields that up to the present year have supplied the industries of that city.

Billings, a large center of population, about 20 miles south of the southern edge of the Bull Mountain coal field and about 50 miles south of Roundup, derives its fuel supply mainly from the Red Lodge and Bear Creek districts, but direct railway connection between Roundup and Billings is a possibility of the future.

Drainage.—The Bull Mountain coal field occupies the higher portion of the main divide between Yellowstone and Musselshell rivers in Rs. 25 to 31 E. The streams draining the north side of the field and entering Musselshell River, named in order from west to east, are as follows: Goulding Creek, Naderman Coulée, Halfbreed Creek, Berrigan Coulée, Parrot Creek, Schnall Coulée, Fattig Creek, and Hawk Creek. The principal creeks which enter Yellowstone River from the southeast portion of the field examined are Buffalo, Hibbard, Cow Gulch, and Railroad creeks. The streams on both sides of the divide are for the most part intermittent, but all of them have deep-cut valleys that are often flooded after heavy showers.

TOPOGRAPHY.

The portion of the Bull Mountain field examined during the season of 1908 has an extreme relief of about 1,300 feet and exhibits a type of topography that is the result of rather mature erosion upon nearly horizontal beds of alternating hard and soft rocks. The traveler passing along the northern boundary of the field on the Chicago, Milwaukee and Puget Sound Railway sees to the south, in the background, high buttes, such as Three Buttes and the main northern Bull Mountain Mesa. Radiating from them in the midground he sees rugged divides which are dissected into mere skeletons by innumerable coulées. In some places heavy horizontal sandstone strata produce extensive flats, which as a rule are utilized for grazing purposes. In the foreground stretches the flood plain of Musselshell River, which where irrigated produces excellent crops of alfalfa and grain. Badland topography is uncommon and is limited to a band of sandy clay shale which outcrops near the base of the coal-bearing rocks.

GEOLOGY.

STRATIGRAPHY.

The upper rocks of the Bull Mountain coal field belong to the Fort Union formation of the Tertiary system. The lower rocks, which rest in apparent conformity upon the Bearpaw shale of the Cretaceous, have by previous writers been either referred to the Laramie or designated "transition beds," between the Cretaceous and Tertiary systems. They are regarded as equivalent to the somber beds of the Miles City field. The upper 1,650 feet of the section contains an abundant fauna and flora, which have been identified as of Fort Union age by F. H. Knowlton and T. W. Stanton. The underlying 200 to 300 feet of somber-colored shale and coarse yellow sandstones, with beds of carbonaceous sandstone and shale, have yielded a few fossils of possible Fort Union age. The bottom portion of the section, comprising the doubtful Laramie or transition beds, is apparently barren of fossils and consists of alternating gray sandstones and clay shales with thin beds of coal.

Stratigraphy of the central part of the Bull Mountain coal field, Montana.

System.	Formation.	Thickness.	Description.
		Feet.	
Tertiary	Fort Union formation	1,650	Yellowish sandstones and shales interstratified with lignite beds.
(?)		200-300	Somber-colored shale and coarse yellow sandstones, with beds of carbonaceous sandstone and shale.
Cretaceous	Laramie (?) formation	1,480	Alternating gray sandstones and clay shales, with thin coal beds.
	Bearpaw shale		Gray to brown shales and clay.

A section of the lower beds is given below to show the proportions of the different rocks and the relative positions of the coal beds.

Section of lower rocks (Laramie?) of the Bull Mountain coal field, near Musselshell, Mont.

Sandstone, gray (base (?) of Fort Union).	Ft.	In.
Sandstone, yellow, coarse, soft	212	4
BIG DIRTY COAL BED.		
Carbonaceous sandstone and shale, with ⅛-inch to 1-inch streaks of coal	10	5
Sandstone, yellow, soft	6	6
Carbonaceous sandstone and shale, with streaks of coal as above	7	9
Sandstone, yellow, coarse, with iron concretions	15	4
Limestone	1	
Sandstone	14	
Coal		8
Shale, yellowish	30	
Sandstone	15	
Coal		4
Shale, gray		4
Coal		8
Shale, gray	34	
Sandstone, with iron concretions	55	
Limestone	3	
Shale, gray	3	4
Coal		3
Bone		3
Coal		7
Shale		4
Coal		3
Sandstone, yellow, weathering into rounded forms	16	
Shale	11	2
Coal		10
Limestone concretions	10	
Shale	30	
Sandstone	15	
Shale	2	
HOMESTEAD COAL BED.		
Coal		11
Shale, carbonaceous		9
Coal	1	1
Shale		1
Coal		11
Shale		1
Coal		6
Shale	18	6
Coal	1	8
Shale	6	
Coal		2
Shale	4	7
Sandstone	2	

	Ft.	in.
Shale	4	
Coal, bone		2
Coal	1	
Shale	10	9
Coal		3
Shale	5	
Sandstone	10	
Shale	1	6
Coal	1	6
Shale	10	
Sandstone	16	
Shale	10	
Coal		10
Shale	2	
Sandstone, with limestone cap	13	
Shale	41	
Sandstone, yellow, coarse, with limestone cap	40	
Shale	179	6
Sandstone	40	
Shale	92	6
Sandstone, yellow and gray	5	
Shale	74	
Sandstone, yellow to gray, weathering to rounded pebbles	30	
Shale, caky, with thin limestone bands	389	
Sandstone, calcareous	3	
Shale	80	
Sandstone	15	
Sandstone, yellow, porous	11	6
Concealed	131	2
Sandstone, brown, thin-bedded	26	5
Shales, clay, gray to brown (Bearpaw shale).		
	1,777	8

The character of the rocks which were identified as Fort Union and which constitute the upper portion of the Bull Mountain section is illustrated graphically in the columnar sections on Plates IV and V. This section, which is a generalization of several sections measured on the north and southeast sides of the mountains, differs from that published by Woolsey[a] for the southwest portion of the field chiefly in the intervals between certain coal beds. The most noticeable difference is the thickening of the beds near the base of the section by about 450 feet.

STRUCTURE.

The central part of the Bull Mountain field has a comparatively simple structure. It consists of a large, shallow synclinal basin, having a general northwestward axial trend, and a rather accentuated lip at its northwestern extremity. The syncline merges on its northern border into a mild anticline whose flanks dip about 5°. The anticline is parallel on the north by a smaller but sharper syncline, the greater portion of which lies to the north of the area shown on the accompanying maps.

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[a] Op. cit.

COAL.

GENERAL STATEMENT.

The coal of the Bull Mountain field is for the most part high-grade subbituminous ("black lignite") or low-grade bituminous. Mining has not been carried on for a sufficiently long period to observe the coal under all conditions of exposure, and thus to determine accurately its "stocking" qualities. If the coal proves to stock well it should probably be classed as bituminous coal. Twenty coal beds that in places attain a thickness of more than 2 feet were studied. The general habit of the beds is lenticular, though several beds are notable exceptions to this rule, and it has been possible to trace their outcrop completely around the mountains. An attempt was made to locate and define the workable portion of the beds by a study of the outcrop, supplemented by drill sections in the northwestern part of the field. The ravines, coulées, and ridges were carefully searched for outcrops of coal. All coals thus discovered were traced and those having a thickness of 2 feet or more were mapped. The traverses of the coal outcrop were made either by compass and pacing or by triangulation, according to the character of the topography. All traverses were tied to land corners. The position of these corners was assumed in general to be correctly given on the maps of the land surveys except along the right of way of the Chicago, Milwaukee and Puget Sound Railway, where the railway survey, being later than the land survey and doubtless more accurate, was accepted. Certain gross inconsistencies in the position of land corners were evident even by the method of work pursued, and these are shown on the maps. These maps indicate the number and character of the corners found, an effort being made to distinguish between government corners, doubtful government corners, corners reported by the railway survey but not visited by members of the party, and corners established by private individuals. The outcrops of the principal coals are platted in solid, broken, and dotted lines, which represent within certain rough limits the thickness of the coal beds and the position of the outcrops with reference to section corners.

DETAILED DESCRIPTIONS.

In this discussion the coals will be taken in order, beginning with the lowest bed and continuing upward to the highest bed in the Bull

Mountains proper. Named in this order, the principal coal beds are the Homestead, Big Dirty, Carpenter, Spendiff, Snyder, Snelling, Roundup, Wildhorse, "C. A.," Buckey, Chandler, Dougherty, Ostrander, Pompey, Saddler, Mammoth, Rehder, Rock Mesa, Carter, Matt, Bull Mountain, Wescott, Strait, Red Butte, Fattig, and Summit.

The thickest and probably best coal of the doubtful Laramie rocks has been called the Homestead bed. The following section, measured in a prospect, illustrates the character of the bed:

Section of Homestead coal bed, in T. 9 N., R. 27 E.

	Ft.	in.
Shale with coal streaks	2	
Coal	1	3
Bone		4
Coal		4
Bone		2
Coal		3
Shale	1	
Coal	1	1
Total coal	2	11

The sample of coal which was taken at this point from the 1-foot 3-inch bench at the top of the bed gave a calorific value of 12,116 British thermal units in the air-dried state, and on this basis alone the coal may be considered a high-grade subbituminous or possibly a low-grade bituminous. The coal, although almost freshly mined, showed marked indications of weather checking. The Homestead bed and its companion thinner beds were deemed unworthy of mapping in the field, and may be dismissed without further discussion.

The Big Dirty coal bed, called by Woolsey[a] the Glendive bed, is not workable in the Bull Mountain field, but in places it produces conspicuous outcrops (P coal, Pls. IV and V) and makes a useful marker by which to limit the area of coal-bearing rocks. In order that this bed may not be confused with any of the valuable coals, its distribution and character will be fully treated.

In the southeastern portion of the field the Big Dirty coal bed does not outcrop continuously, but its blossom was found in the southeast corner of T. 5 N., R. 28 E., and near the southeast corner of supposed sec. 23, T. 5 N., R. 29 E. (unsurveyed), the bed consists of 3 feet of carbonaceous shale and sandstone. It outcrops conspicuously along Cow Gulch, in the southeastern part of the township, where it consists of about 4 feet of carbonaceous shale. Outside of the area mapped during the present year this coal was seen in the southeastern portion of T. 5 N., R. 32 E., on Buffalo Creek, and at this point consists of 20 feet of carbonaceous shale and sandstone, with thin streaks of coal. The Big Dirty coal bed has not yet been examined between this point and the center of T. 9 N., R. 30 E., where it is exposed as 11 feet of carbonaceous shale and sandstone, with the characteristic thin, irregular streaks of coal. In sec. 18, directly north of D. Chandler's prospect on the Carpenter coal, the Big Dirty thins to about 5 feet. The outcrop continues westward along the northern rim of the Fort Union basin, and was measured in the northwestern portion of T. 9 N., R. 28 E., where it shows two benches of carbonaceous shale and sandstone 4 and 3 feet thick, containing thin seams of coal and separated by a parting of sandstone 2 feet 6 inches thick. The outcrop continues nearly due west from this point to the northwest corner of the township, where it rounds the end of the syncline and takes a nearly southwest course. The bed as measured in sec. 20, T. 9 N., R. 27 E., consists of 5 feet of carbonaceous sandstone and shale, with thin seams of coal and 1 foot of dirty coal at the base. The outcrop crosses Musselshell River in the northeastern part of T. 8 N., R. 27 E., and thence runs approximately west, aside from the irregularities due to the topography. A prominent outcrop may be seen in the railway cut in sec. 3, one-half mile east of the Arkwright Sheep Company's ranch, where a thickness of about 6 feet of coaly shale is exposed. To the west, in secs. 5 and 6, the outcrop is very conspicuous, as it covers a dip slope for a considerable distance. Although it was not possible to obtain an actual measurement of the bed in this part of the township, it appears to be at least 20 feet thick and is composed of alternating carbonaceous shales and sandstones, with thin layers of coal. Fragments of the eroded coal collect in the coulees and appear to be of a fairly good quality. The outcrop continues across the next township to the west in the same general westerly direction and is well exposed at some places, especially in sec. 2, north of the river road, in an isolated butte. At this point it shows at least 2 feet of dirty coal. There is a more prominent outcrop in sec. 9, where the bed, 6 feet thick, is exposed in a railway cut. The amount of coal, however, is small and carbonaceous shale and sandstone predominate. In sec. 18 the bed is 10 feet thick, but consists mainly of dirty coal and carbonaceous shale. In T. 8 N., R. 25 E., the outcrop of the Big Dirty bed swings toward the northwest from a point in sec. 14 about 1 mile west of Roundup. The thickness in this township, as shown by several measurements, is about 10 feet, but the interbedded carbonaceous shale and sandstone predominate over the coal. The bed was next observed in the township to the south, where it outcrops near the Elso schoolhouse. The following section was measured at this point:

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[a] Woolsey, L. H., op. cit., p. 66.

Section of Big Dirty coal bed, near Elso schoolhouse, in sec. 7, T. 7 N., R. 25 E.

	Feet.
Carbonaceous shale, sandstone, and coal	6
Shale	2
Carbonaceous shale, sandstone, and coal	4

In the township to the west (T. 7 N., R. 24 E.), the Big Dirty coal bed outcrops on Kern Creek at two points. At the upper locality, which is about 4 miles from the last-mentioned section, it has the following composition:

Section of Big Dirty coal bed, in T. 7 N., R. 24 E.

	Ft.	In.
Shale, bituminous, with streaks of coal	2	11
Coal		10
Dirt		8
Bone		½
Coal		6
Shale, bituminous		5
Coal		3
Shale, bituminous	1	5
Coal		5
Shale, bituminous		10
Coal		½
Bone		2
Clay, sandy		6
Coal		3
Total coal	2	3½

The lower outcrop on Kern Creek about 2 miles from its mouth shows 2 feet of coal near the bottom of the bed. Coal taken from the bed at this point has been used by several ranchers with fairly good results, but it contains a large amount of ash and slacks in a short time. The probability of a bed of this character improving with depth or distance back from the outcrop is too remote to be considered, and capital expended in its development would undoubtedly be wasted.

The Carpenter coal is named from the creek on which it is mined in T. 9 N., R. 30 E. This bed is 450 feet stratigraphically above the Big Dirty coal bed. The main outcrop extends along the northern and eastern edges of the Bull Mountain field, and although it was not examined in detail, certain general statements concerning it can be made.

The Carpenter coal bed has the following section at W. C. Grant's opening in sec. 26, T. 9 N., R. 30 E., which may be considered typical of the thicker portion of the bed.

Section of Carpenter coal on Carpenter Creek.

	Ft.	In.
Coal, and some mineral charcoal	5	
Bone		2
Coal	1	1
Shale		1½
Coal, with six ⅛-inch partings	2	11
Total coal	9	

It thins gradually to the west; in T. 9 N., R. 29 E., it averages about 4 feet in thickness and in T. 9 N., R. 28 E., so far as could be observed, it is less than 2 feet thick. A closed outcrop of coal about 2 feet 8 inches thick which may belong to this bed is exposed on Fishel Creek in T. 8 N., R. 29 E., about three-fourths of a mile above August Schrader's ranch.

Bore-hole information in the vicinity of Musselshell post-office shows that the bed thins toward the south. The thickness of the bed and its position in the section indicate that the coal of the Fishel Creek locality may be safely correlated with the Carpenter coals. An exposure of coal which is probably an outcrop of the Carpenter bed was seen in the northwestern part of T. 7 N., R. 31 E. At this point, as the following section shows, the coal is separated into four benches by partings.

Section of Carpenter coal bed in T. 7 N., R. 31 E.

	Ft.	In.
Coal		6
Sandstone, bituminous		½
Coal	1	2
Shale	2±	
Sandstone	26	
Shale	2±	
Sand	1	2
Coal	1	2
Shale	1	11
Coal	1	7

The partings appear to thicken toward the southwest, but no measurements were taken showing more than 2 feet of coal. The better portion of the Carpenter coal bed therefore appears to lie in Tps. 8 and 9 N., Rs. 29 and 30 E. Further work is necessary, however, to determine the exact conditions under which these beds occur in the northeastern portion of the field. An analysis of a sample of the Carpenter coal given in the table on page 79 shows a calorific value somewhat lower than that of the Roundup coal.

Between the Carpenter and Roundup coal beds on Fattig Creek a number of thin coal beds, the Snelling, Snyder, and Spendiff (Ob, Oc, Od coals, Pl. V), locally show sections having from 1 to 3 feet of coal. These beds are, however, relatively unimportant and do not merit further discussion.

The Roundup coal bed is about 600 feet stratigraphically above the Big Dirty coal bed, and at present is commercially the most important coal in the field, as all the active mines, namely, shafts Nos. 1 and 2 of the Republic Coal Mining Company and the Commercial mine of the Roundup Coal Mining Company, are located upon this bed. The coal is at present mined only in T. 8 N., R. 25 E. (Oa coal, Pl. V), but an abandoned prospect formerly operated by W. C. Grant in T. 8 N., R. 29 E. is apparently located on the same bed.

The westernmost outcrop of the Roundup coal near the north boundary of T. 7 N., R. 25 E., presents a scarcely workable section, but in sec. 33, T. 8 N., R. 25 E., it is thicker, as shown below:

Section of Roundup coal bed in sec. 33, T. 8 N., R. 25 E.

	Ft.	In.
Coal		2
Sandstone	1	
Coal	1	
Shale	1	8
Coal	1	6
Total coal	2	8

From this point the outcrop runs nearly due north to Musselshell River, north of which for about a mile it swings to the west, and thence extends roughly northward (except for irregularities due to the topography) to the nose of the main Bull Mountain syncline in sec. 8, T. 8 N., R. 25 E. A typical section along a portion of the bed is given below:

Section of Roundup coal bed in sec. 16, T. 8 N., R. 25 E.

	Ft.	In.
Bone		3
Coal	6	
	6	3

From this locality it runs nearly southeast to the Commercial mine of the Roundup Coal Mining Company, where the bed is reported to attain a maximum thickness of 6 feet. About half a mile to the southeast, however, in a slope in the NW. ¼ NE. ¼ sec. 23, it contains only 4 feet of coal, but the thickness increases toward the southeast so that in the Republic mine No. 1 it ranges from 5 feet 9 inches to 6 feet 1 inch and has a rather constant roof of about 4 to 6 inches of bituminous shale, overlain by heavy sandstone.

The next opportunity to examine the bed is in sec. 18, T. 8 N., R. 26 E., about one-eighth of a mile west of J. W. Newton's ranch, and here, owing to the burning, it is impossible to make a careful measurement of the coal. It is at least 5 feet thick. From this point the outcrop is projected across the flood plain of the river to an exposure in sec. 17, where the bed shows the following section:

Section of Roundup coal bed in sec. 17, T. 8 N., R. 26 E.

	Ft.	In.
Coal		3½
Bone		½
Coal	3	7
Total coal	3	10½

Near Berrigan Coulee the character of the section begins to change, a portion of the coal being replaced by carbonaceous shale. The amount of shale seems to increase gradually toward the east to a certain point and then to decrease to the east fork of Parrott Creek, where the following section was measured:

Section of Roundup coal bed in sec. 19, T. 8 N., R. 27 E.

	Ft.	In.
Coal		3
Shale		3
Shale, carbonaceous		4
Coal	3	3
Total	3	6

The coal bed at this point seems to have recovered its characteristic features and the coal maintains the same quality and thickness to Fattig Creek. On the west side of this stream the following section is exposed:

Section of Roundup coal bed in sec. 32, T. 8 N., R. 28 E.

	Ft.	In.
Shale, carbonaceous		8
Coal		5
Shale		1
Coal	1	
Shale		½
Coal		7½
Total coal	2	½

From this point eastward the coal undergoes a rapid deterioration into shale and decreases in thickness until it measures only 1 foot 6 inches in sec. 28, T. 8 N., R. 28 E.

The Roundup coal ranges in quality from a high-grade subbituminous to a low-grade bituminous, and has a calorific value of more than 10,000 British thermal units in the air-dried sample. It is a good coal for steam purposes and appears to withstand shipment well if mined under sufficient cover.

The Wildhorse coal is relatively unimportant in the area examined, although its eastern continuation from the point where the bed crosses the east boundary of T. 5 N., R. 27 E. (O coal, Pl. IV), was mapped and numerous measurements were obtained, of which the following is representative of the thicker portion of the bed:

Section of Wildhorse coal bed in sec. 18, T. 5 N., R. 28 E. (unsurveyed).

	Ft.	In.
Coal		2
Coal, with ⅛-inch to ¼-inch streaks of shale		4
Coal	2	9
Total coal	2	11

On the north side of the Bull Mountains the Wildhorse bed where present is represented by less than 2 feet of coal. It is possible that in the development of the field the Wildhorse and Roundup coal beds will be found to be identical, although the evidence in hand does not warrant that interpretation.

The "C. A." coal is 95 feet above the Wildhorse coal bed and persistent in the southeast portion of the field. It reaches its greatest thickness in sec. 36, T. 6 N., R. 28 E. (Na coal, Pl. IV), thinning both to the west and to the east. It is of poor quality, appearing on the outcrop to be nearer lignite than subbituminous, and is characterized by a very persistent parting, as shown in the following typical section:

Section of "C. A." coal in sec. 9, T. 5 N., R. 28 E.

	Ft.	In.
Coal		6
Shale		5
Coal	1	6½
Total coal	2	½

The Buckey coal occurs 60 feet above the "C. A." bed, and though prominent in the area examined in the previous year by Woolsey is of slight importance in that portion of the field mapped during 1908. The bed shows a workable thickness for a short distance along the western border of T. 5 N., R. 28 E. (N coal, Pl. IV), but nowhere exceeds 2 feet 6 inches in thickness.

Between the Buckey and the Dougherty coal the rocks are generally barren of coal beds. The Chandler coal, 40 feet below the Dougherty, was found near Railroad Creek, Cow Gulch, and Fattig Creek. It is usually thin and of poor quality.

The Dougherty coal is persistent throughout the area examined and is workable except in T. 8 N., R. 26 E. (M coal, Pls. IV and V), and portions of T. 7 N., Rs. 26 and 27 E. It is 510 feet stratigraphically above the Roundup coal, as determined by a leveled section near Fattig post-office and a bore-hole section in T. 7 N., R. 26 E., on the west fork of Parrott Creek. A typical section of the workable portion of the bed in sec. 17, T. 7 N., R. 26 E., in the northwestern part of the field shows 3 feet 8 inches of coal.

According to information gathered from the bore holes the bed appears to thin in the eastern part of the same township, but to the north the measurements on the outcrop range from 1 foot 6 inches to 2 feet 1 inch. In a section in T. 7 N., R. 27 E., on one of the forks of Parrott Creek, it again increases in thickness.

Section of Dougherty coal in sec. 22, T. 7 N., R. 27 E.

	Ft.	In.
Coal	2	6
Shale		4
Coal		2
Total coal	2	8

The shale parting of the above section is persistent and thickens eastward to a maximum of 9 inches. The following section is representative of the coal bed near the head of the dry fork of Hawk Creek:

Section of Dougherty coal in sec. 5, T. 6 N., R. 29 E. (unsurveyed).

	Ft.	In.
Coal	1	5½
Shale		2
Shale, bituminous		5
Coal	2	1½
Total coal	3	7

The sections to the west of this point show a gradual increase in the thickness of this coal until the maximum is apparently reached in Cow Gulch, where the following measurement was made:

Section of Dougherty coal bed in sec. 10, T. 6 N., R. 28 E.

	Ft.	In.
Coal		1½
Shale		1
Coal	4	9
Total coal	4	10½

From this point the outcrop takes a general southwesterly course and the bed is extremely variable in thickness, thinning to 1 foot 6 inches in sec. 20, T. 6 N., R. 28 E., but in sec. 21 reaching 2 feet 11 inches. At a point where the south fork of Railroad Creek enters the township it shows the following section:

Section of Dougherty coal bed in sec. 31, T. 6 N., R. 28 E.

	Ft.	In.
Coal, poor		1
Coal	2	½
Shale		1
Coal		6½
Shale		4
Coal		1
Total coal	2	9

The coal of the Dougherty bed is undoubtedly high-grade subbituminous and appears to be one of the cleanest and most uniformly thick coals of the field. A sample taken from the outcrop at Cow Gulch showed, after being air dried, a calorific value of 10,771 British thermal units. The Dougherty coal generally has an excellent sandstone roof and a shale floor, two valuable factors which, together with its quality, should lead to early development of this bed.

About 60 feet above the Dougherty coal in Rs. 28 and 29 E., the Ostrander coal (La coal, Pls. IV and V) is persistent and, though commonly thin, it locally assumes a workable thickness, as shown in the following representative section:

Section of Ostrander coal bed in sec. 16, T. 6 N., R. 28 E.

	Ft.	In.
Coal		6
Bone		2
Coal	3	
Total coal	3	6

The same coal in the northern part of the field, in T. 8 N., R. 26 E., where measurements have been obtained, ranges from 1 foot 4 inches to 3 feet.

The Pompey coal, one of the most promising in the southwestern part of the Bull Mountain field, is apparently absent in the area covered by this report.

In the northeastern part of T. 7 N., R. 27 E., on Parrott Creek, the Saddler coal bed (Ka coal, Pl. V) occurs about 40 feet below the Mammoth bed and ranges in thickness from about 1 foot 6 inches of coal to a maximum of 2 feet 2 inches. In the remainder of the field this bed is thin except at a point almost directly north of the easternmost of the Three Buttes, where it shows the following section:

Section of Saddler coal bed in sec. 32, T. 7 N., R. 28 E.

	Ft.	In.
Coal	1	6
Shale		½
Coal	2	5
Total coal	3	11

The Mammoth coal bed (N coal, Pls. IV and V) is the thickest bed occurring in any part of the field so far examined. The portion mapped during the present year, combined with that given by Woolsey,[a] closes the outcrop around the Bull Mountains.

The Mammoth coal bed was examined by Eldridge,[b] and while, in general, results similar to his were obtained by the Geological

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[a] Woolsey, L. H., op. cit., pp. 60–75.

[b] Eldridge, G. H., Montana coal fields: Tenth Census, vol. 15, 1886, pp. 753–755.

Survey party, yet different interpretations have been given to some of the facts. For example, the outcrop is shown on the accompanying maps (K coal, Pls. IV and V) as extending not so far east as on the earlier map of Eldridge, and in the northwestern part of the field the coal bed now called the Rehder is undoubtedly what Eldridge designated as the upper bench of the Mammoth. It is clearly possible that Eldridge's interpretation may be correct and final determination must await the development of mining. The Mammoth coal bed is undoubtedly workable throughout the part of its area mapped in 1908, although a number of small partings are invariably present and here and there reach such a thickness that it is difficult to decide from the section whether portions of the same bed or distinct beds are represented. For example, in the excellent exposure at Schlaberg camp, on Fattig Creek, a parting enters and thickens at the rate of 3 feet in 100, and yet the same parting measures only 10 feet 6 inches 6 miles distant at Douglas camp, on Cow Gulch, where the section given below was measured:

Section of Mammoth coal bed in sec. 10, T. 6 N., R. 28 E.

	Ft.	In.
Coal	8	6
Shale		3
Sandstone	2	
Shale		6
Sandstone, gray	10	
Shale		6
Coal	2	
Shale	1	
Coal	3	
Total coal	13	6

This section was sampled for analysis and the upper bench gave a fuel value of 11,610 British thermal units and the lower bench 10,771 British thermal units in air-dried samples.

The extensive burning of the coal along the outcrop of the Mammoth bed, especially on both sides of the divide between Parrott and Halfbreed creeks, makes it difficult to obtain sufficient measurements to estimate the content of the coal bed in the northwestern part of the field. The effect of the burning itself, however, may be taken as a rough indication of the thickness of the coal bed, and it may be safely assumed that the bed is at least 3 feet thick inside of the burnt zone, which is probably not over 200 feet wide.

The Rehder coal bed (J coal, Pl. V) occurs about 35 feet higher in the geologic section than the Mammoth bed, and is practically limited in distribution to T. 7 N., R. 26 E., and the southwest quarter of T. 7 N., R. 27 E. The outcrop is extensively burned, a fact which renders it difficult to obtain satisfactory measurements. However, the following is believed to be a representative section:

Section of Rehder coal bed in sec. 12, T. 7 N., R. 26 E.

	Ft.	In.
Coal	3	
Bone		1
Coal		11
Total coal	3	11

About 45 feet above the Rehder coal, or 80 feet above the Mammoth coal, there is a persistent but erratic coal bed called the "Rock Mesa" coal (I coal, Pl. IV). This bed is everywhere present in the southwestern portion of the field, as it is in the area examined in 1908, and in both localities it contains persistent partings which within short distances are likely to attain proportions deleterious to the commercial value of the coal. This bed is usually covered by a shale roof. The following section is typical for T. 7 N., R. 26 E.:

Section of Rock Mesa coal bed in sec. 27, T. 7 N., R. 26 E.

	Ft.	In.
Coal	1	7
Shale		2
Coal		10
Total coal	2	5

In T. 7 N., R. 27 E., the maximum observed thickness of the coal is 3 feet 7 inches, which occurs in sec. 20, but there are many places in this township where the bed contains only small amounts of coal or the outcrop is obscured by grassed and forested slopes. In the eastern part of the field the Rock Mesa coal ranges from less than 1 foot 6 inches to a maximum of 3 feet 4 inches, but in most places it is less than 3 feet thick.

On the east side of the Three Buttes, about 50 feet above the Rock Mesa bed, is a coal bed which has been named the Carter coal (Ha coal, Pls. IV and V). This bed shows a thickness of 2 feet 8 inches in sec. 9, T. 6 N., R. 28 E., at the head of Cow Gulch, but thins in both directions, and so far as known is unimportant elsewhere.

Between the Carter coal and the Bull Mountain coals is the Matt coal, which attains some importance in the southwestern part of the field, but the measurements obtained in the area treated in this report were less than 1 foot, so that the bed need not be considered here.

The Bull Mountain coals (F and G coals, Pls. IV and V) in general outline the high mesas and buttes in the south-central portion of the field, and occur at a distance of about 130 feet above the Rock Mesa coal. This interval is 85 feet less than that observed by Woolsey in the southwestern portion of the Bull Mountains.

The two Bull Mountain beds are separated by only 12 to 20 feet of sandstone and shale. The upper bed is usually underlain and overlain by conspicuous dark-gray clay shale 20 to 30 feet thick. The upper bed is in most places the thicker of the two and the following may be taken as an average section of both coal beds:

Section of Bull Mountain coals in sec. 15, T. 6 N., R. 28 E.

	Ft.	in.
Coal (F)	4	5
Shale	12	
Coal (G)	2	11

In many places one of the beds, usually the lower one, falls below 2 feet in thickness, and here and there both beds are thin and of doubtful value.

The coal-bearing area lying above the Bull Mountain coals is small, but comprises a number of beds (A, B, C, D coals, Pl. V) spaced at intervals of 15 to 60 feet. Many of these beds have probably lost a large part of their coal from burning, which baked and reddened the tops of the high buttes and mesas, so that thorough prospecting is necessary to locate the undestroyed portions. These higher coal beds are relatively inaccessible and therefore unimportant at the present time. The names, intervals, and known relative importance of these coals is shown on the maps and in the columnar section, except a small outlier in the Three Buttes section of the field, which was not mapped because of its insignificant area.

CHARACTER.

PHYSICAL PROPERTIES.

The coals of the Bull Mountain field are pitch black to brown black in color and when rubbed on unglazed porcelain leave a darkish-brown to black streak. They commonly show lustrous bands which vary in character, ranging from dull waxy or bright submetallic on a fresh fracture to a dull satiny luster in the parts of the coal bearing mineral charcoal, or "mother coal." The waxy and bright bands range from less than one-eighth inch to over 1 inch in thickness.

Joints have been observed in all the coal beds where they are well exposed. The joint planes are parallel to joints in the roof, many of which are continuations of those in the coal. The joint planes are in general nearly at right angles to each other and in places constitute well-defined face and butt cleats, so that the coal when shot down in the mine falls in roughly cubical blocks. The lumps of coal show a tendency to break up into smaller cubes on exposure to the atmosphere. Some of the banded coal on continued exposure disintegrates into platy flakes, while that which lacks the banded structure resists the process of disintegration for a longer period, but in nearly all cases finally breaks up by checking off in small chips with conchoidal surfaces. A net of pyrite or marcasite, together with their alteration products, and fine powdery gypsum is occasionally found along the joint planes. When the coal is broken by a blow from a hammer conchoidal to smooth fracture surfaces are likely to predominate over cleavage surfaces parallel to the joint planes. The coherence ranges from brittle to tough, and the impact is dull rather than metallic. The texture of the coal is dense to laminated and only in a few places shows slight indications of a woody character. The coal is of low specific gravity. The accessory substances fall into several groups—sulphides, sulphates, and hydrocarbons. The sulphides, marcasite and pyrite, have already been noted. In addition to gypsum, the sulphate mentioned above, epsomite has been found in fairly large quantities in connection with some of the higher coals, especially the lower Bull Mountain (G) coal. With this particular coal the epsomite forms a surficial deposit attaining a maximum thickness of about a foot directly underlying the coal bed in sec. 8, T. 6 N., R. 28 E. Resin and sulphur are locally present in small rounded masses irregularly and sparsely scattered through the coal. The coal burns with a yellowish flame of moderate length and occasionally gives off a strong, pungent sulphurous odor. In burning the coal decrepitates rapidly, and when used in locomotives the fragments blow out of the stack or fall between the grate bars. These difficulties have been overcome to a considerable extent, however, by modifying the character of the forced draft and by using specially constructed grates. It is advisable to admit a rather large amount of air above the grate and also to distribute the coal unevenly upon the grate to prevent choking the process of combustion. The ash is fine, ranges from gray to reddish-yellow in color, and is not clinkery unless the coal is dirty.

CHEMICAL PROPERTIES.

As the examination of the Bull Mountain field was practically limited to a study of the coal outcrops it was not possible to collect more than a few unweathered samples for analysis, owing to the lack of mining developments. The samples were collected in conformity, as nearly as possible, with the regulations of the United States Geological Survey, and the analyses were made under the direction of F. M. Stanton at the Pittsburg laboratory. An examination of the coals as received from the mine shows that the moisture content ranges from 12.69 to 22.77 per cent, the amount of ash from 4.15 to 7.70 per cent (exclusive of Roundup No. 6235, a bore-hole sample whose high ash is due to the inclusion of rock dust), and the British thermal units from 8,863 to 11,034. The only strictly fresh sample (Roundup No.

5900) heads the list and the Carpenter sample (No. 7197) foots it. The last sample was taken under very thin cover, and probably represents a weathered condition of the coal, not apparent on visual examination. The loss of moisture on air drying ranges from 2.70 to 16.30 per cent, the minimum representing an unweathered facies and the maximum a sample taken on the outcrop of the Dougherty coal.

Analysis of coal samples from the Bull Mountain field, Montana.

[F. M. Stanton, chemist in charge.]

	Name of coal bed	Homestead.	Carpenter.	Roundup.			Dougherty.	Mammoth.	
	Laboratory No	6829	7197	5800	6235	7195	6830	6828	6831
	Sample as received:								
Prox.	Moisture	18.14	22.77	12.69	18.35	16.66	21.56	18.65	17.43
Prox.	Volatile matter	27.22	27.00	28.71	23.34	27.85	30.46	29.62	31.16
Prox.	Fixed carbon	50.49	45.58	50.90	39.06	48.07	43.02	46.61	48.09
Prox., Ult.	Ash	4.15	4.65	7.70	19.25	7.42	4.96	5.12	3.32
Ult.	Sulphur	.88	.32	.54	.31	1.00	.72	.78	.35
Ult.	Hydrogen	5.46	5.47	5.44	....	5.61	....	....	....
Ult.	Carbon	60.48	53.49	64.26	....	59.22	....	....	....
Ult.	Nitrogen	.77	.93	.88	....	.97	....	....	....
Ult.	Oxygen	28.26	35.14	21.18	....	25.78	....	....	....
	Calories	5,789	4,924	6,130	4,799	5,681	5,009	5,495	5,711
	British thermal units	10,420	8,863	11,034	8,638	10,226	9,016	9,892	10,280
	Loss of moisture on air drying	14.00	13.50	2.70	13.70	7.20	16.30	14.80	12.90
	Air-dried sample:								
Prox.	Moisture	4.81	10.72	10.27	5.39	10.19	6.28	4.52	5.20
Prox.	Volatile matter	31.65	31.21	29.51	27.04	30.01	36.39	34.76	35.78
Prox.	Fixed carbon	58.72	52.69	52.31	45.26	51.81	51.41	54.71	55.21
Prox., Ult.	Ash	4.82	5.38	7.91	22.31	7.99	5.92	6.01	3.81
Ult.	Sulphur	1.02	.37	.56	.35	1.08	.82	.92	.40
Ult.	Hydrogen	4.54	4.59	5.28	....	5.18	....	....	....
Ult.	Carbon	70.32	61.84	66.04	....	63.82	....	....	....
Ult.	Nitrogen	.90	1.08	.91	....	1.04	....	....	....
Ult.	Oxygen	18.40	26.74	19.30	....	20.89	....	....	....
	Calories	6,731	5,693	6,300	....	6,122	5,984	6,450	6,558
	British thermal units	12,116	10,247	11,340	10,000	11,020	10,771	11,610	11,804
		Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
	Thickness of bed (total coal)	2 11	5 3	4	5	2 6	4 10½	5	8 6
	Thickness of part sampled	1 3	4 6	4	5?	2 6	4 10½	5	6

6829. Upper 1 foot 3 inches of Homestead coal bed, about 12 miles northwest of Musselshell post-office.
7197. All except upper 9 inches of Carpenter coal bed about 6 miles east of Musselshell post-office.
5800. Full thickness of Roundup coal bed, SW. ¼ NE. ¼ sec. 23, T. 8 W., R. 25 E.
6235. Full thickness (?) of Roundup coal bed, bore-hole sample, T. 6 N., R. 26 E.
7195. Full thickness of Roundup (?) coal bed, about 6 miles south of Musselshell post-office.
6830. Full thickness of Dougherty coal, NW. ¼ SE. ¼ sec. 10, T. 6 N., R. 28 E.
6828. Full thickness of lower bench of Mammoth coal bed, SW. ¼ NW. ¼ sec. 10, T. 6 N., R. 28 E.
6831. Lower 6 feet of upper bench of Mammoth coal bed, SW. ¼ NW. ¼ sec. 10, T. 6 N., R. 28 E.

A better comparison of the coals can be made from the analyses on the air-dried basis and in these the moisture ranges from 4.52 to 10.70 per cent and the British thermal units from 10,000 to 12,116. As there is good reason for believing that the other coals will approximate the Roundup coal when sampled under mine conditions, the Roundup may be taken as a type of the Bull Mountain coals. If compared with several coals from adjacent fields, on the basis of the data in the following table, the Roundup coal ranks well, especially in total carbon when considered apart from its ash and moisture.

Comparison of various Montana and Wyoming coals.

	Laboratory No.	Air dried.				Ash free.		
		Moisture.	Ash.	Fixed carbon.	British thermal units.	Moisture.	Total carbon.	British thermal units.
Roundup	5800	10.27	7.91	52.31	11,340	11.15	71.71	12,314
Red Lodge	3590	7.34	12.57	42.17	10,270	8.39	66.56	11,746
Bear Creek	5822	6.26	13.65	44.69	11,444	7.25	67.64	12,789
Lewistown	5872	2.79	9.04	52.37	11,563	8.56	73.23	12,712
Lewistown	5473	6.59	8.45	62.79	10,570	7.19	68.58	11.545
Sheridan (Carneyville)	5388	17.30	3.68	42.38	10,096	17.96	61.02	10,548

	Laboratory No.	Ash and moisture free.			Ratios, air dried.		
		Total carbon.	Total hydrogen.	British thermal units.	Fuel.	C/H.	C/O.
Roundup	5800	80.71	0.04508	13,860	1.77	12.5	3.42
Red Lodge	3590	72.66	.05187	12,714	1.11	11.7	2.78
Bear Creek	5822	72.91	.05237	14,288	1.26	11.9	3.64
Lewistown	5872	80.09	.03657	13.902	1.70	13.6	4.85
Lewistown	5473	74.90	.04411	12,441	1.84	14.0	2.92
Sheridan (Carneyville)	5388	74.37	.04746	12,777	1.16	10.4	1.93

DEVELOPMENT.

Coal mining in the Bull Mountains is restricted to the Roundup bed in the northwestern part of the field, on Musselshell River and a fork of Halfbreed Creek. The thriving town of Roundup is an indication of the rapid development of the coal-mining industry. Early in the eighties coal of workable thickness was known here and a carload was taken out by William Crane and shipped to Marcus Daly at Anaconda, but not until 1907 was commercial mining begun. In the fall of that year the Republic Coal Company attempted to work the Roundup bed by a slope extending under the Musselshell River, but the cover, consisting mainly of alluvium, permitted the entrance of great quantities of water, which rendered this plan unfeasible. A shaft on the south side of the river, in sec. 24, T. 8 N., R. 25 E., which had been originally intended for an air shaft, was enlarged and used as the main shaft for mine No. 1. The coal was penetrated at a distance of 137 feet from the surface and is mined by the room and pillar method. Mule haulage is used underground. The mine is equipped with a complete pumping, hoisting, and loading plant. The coal as it comes from the mine is clean and is used mine run, or stored in pockets that feed directly into coal cars. The joints in the overlying rocks are charged with water, which flows into the new workings until exhausted. The water that thus drains into the mine has, however, been successfully handled by the pumps. This water is of excellent quality and will probably be utilized by the town of Roundup. The production of mine No. 1 for 1908 is reported to have been 39,348 tons.

During 1908 the Republic Coal Company acquired coal rights in sec. 36 of the same township and started operation on mine No. 2 near the center of the section. The coal is reported to have been encountered in the main shaft at a depth of 347 feet from the surface on March 11, 1909, and is said to be 5 feet thick at this point. An extensive pumping, hoisting, and loading plant is under construction. Mine No. 2 has been connected with the main line of the Chicago, Milwaukee and Puget Sound Railway by a spur up Halfbreed Creek to the mine.

In October, 1908, the Roundup Coal Mining Company opened in sec. 23, T. 8 N., R. 25 E., a commercial mine consisting of a slope, with adequate equipment for mining, hoisting, and loading. This mine is connected with the main line of the Chicago, Milwaukee and Puget Sound Railway by a spur and is designed to supply coal for consumption of towns along the railway, the entire production of the Republic Coal Company being utilized by the railway company.

Local demands for coal in Roundup and other settlements along the Chicago, Milwaukee and Puget Sound Railway will increase as a result of the growth of manufacturing industries and gain in population.

THE MILK RIVER COAL FIELD, MONTANA.

By Leon J. Pepperberg.

INTRODUCTION.

Field work.—This paper is a preliminary statement[a] of the results of a detailed survey of a part of the Milk River coal field, Montana, made during the summer of 1908 by the writer with the assistance of V. H. Barnett. The object of this survey included not only the geologic and economic investigation of the area but primarily the classification of the public lands with respect to coal. Consequently the work was conducted with the view of ascertaining the extent of the coal areas and their relations to legal land subdivisions. In carrying on this work the geologic data were platted upon a base of recent topographic maps made by the United States Geological Survey on a scale of approximately 1 inch to the mile with a contour interval of 20 feet. This base covers the entire area examined, with the exception of a narrow strip about 1¼ miles wide along the southern part of T. 32 N., Rs. 15 to 21 E., inclusive.

Previous reports.—Very little has been written concerning the geology or coal of this region. The most important work published by previous investigators is that of T. W. Stanton and J. B. Hatcher.[b] Their report, which deals with the geology and paleontology of the Judith River formation, contains a review and bibliography of publications relating to this formation in Montana and Canada. Brief mention of the coal of this field is made in a report by J. P. Rowe[c] and the field is referred to in several reports of the inspector of coal mines of the State of Montana and in the "Mineral Resources of the United States."[d]

The glacial geology of the region has been briefly discussed by F. H. H. Calhoun,[e] and papers describing the prominent features of the Bearpaw Mountains with special reference to igneous rocks have been published by W. H. Weed and L. V. Pirsson.[a]

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[a] A detailed report is now in the course of preparation, to be issued as a separate bulletin of the United States Geological Survey.

[b] Geology and paleontology of the Judith River beds, with a chapter on fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey, No. 257, 1905.

[c] Montana coal and lignite deposits: Bull. Univ. Montana No. 37 (Geol. series No. 2), 1906, pp. 39–40.

[d] Mineral Resources U. S. for 1907, pt. 2, U. S. Geol. Survey, 1908, pp. 149–150.

[e] The Montana lobe of the Keewatin ice sheet: Prof. Paper U. S. Geol. Survey No. 50, 1906.

Location and extent.—The part of the Milk River coal field herein described is located in Chouteau County in north-central Montana. The greater portion lies in the Milk River drainage basin, but it also includes a strip in the extreme southwest corner which drains into Missouri River. The area examined embraces Tps. 32 to 34 N., Rs. 12 to 24 E., inclusive, along Milk River and the main line of the Great Northern Railway, and an irregular tract from the north boundary of T. 31 N. to the south boundary of T. 26 N., Rs. 10 to 14 E., inclusive, along the Montana Central division of the Great Northern Railway. The area as described includes over 2,000 square miles, but only that part which contains coal of importance is shown on the accompanying map (Pl. VI).

TOPOGRAPHY AND GEOGRAPHY.

The area under consideration is situated in the northwestern part of the Great Plains region. For the most part it is covered with a fair growth of grass and scattered patches of sagebrush. Trees are noticeably absent except along Milk River and its larger tributaries east of Havre, where cottonwood, willow, and underbrush grow close to the drainage ways. When viewed from the highlands the country has a rolling aspect, exhibiting no abrupt changes except where tributaries to the main river have eroded deep channels in passing from the higher land to the valley and where a few lava buttes south and southwest of Havre stand out prominently in comparison to the surrounding flat, treeless plains. In the extreme northeastern portion of the area the bench land has an altitude of 3,220 feet while the lowest point in the southeast corner is 2,320 feet above sea level. The average elevation of the area examined is 2,600 to 2,800 feet.

Almost the entire region under discussion is drained by Milk River, which enters the area in the northwest corner at an elevation of about 2,570 feet. It flows through a narrow, steep-walled valley in a southeasterly direction for about 14 miles and then makes an abrupt turn to the east and continues in this direction for about 24 miles. The course of the river from this point is almost due northeast for 4 miles, beyond which it flows in an east-southeast direction until it crosses the south boundary of the area at an elevation of 2,320 feet above the sea. Within the area examined Milk River flows circuitously about 114 miles in a distance of about 70 miles, forming numerous oxbows, cut-off lakes, and wide migrating meanders on its way. It has a fall of 230 feet, or approximately 2 feet to the mile. The valley of Milk River in the western part of the field is narrow and steep walled, some of the cliffs rising 200 feet above the water level. It has been pointed out by Calhoun[a] that Milk River now occupies the preglacial valley of the Missouri, which formerly flowed south of Havre and was joined by the preglacial Milk about 3 miles east of that city near Stringfellow's ranch. At this point the preglacial Missouri crossed the present course of Milk River in a northeasterly direction and the decrease in the width of the valley below Stringfellow's ranch is conspicuous, but at Yantic Milk River reenters the broad valley formerly occupied by the Missouri and follows the preglacial channel until it leaves the area under discussion. At Yantic the Milk River canyon, which has had an average width of less than a mile, spreads out abruptly to one 3 to 4 miles in width. The cliffs recede and become less abrupt, and the stream is small in comparison with the valley it occupies.

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[a] Am. Jour. Sci., 4th ser., vol. 1, 1896, pp. 283-301; vol. 2, 1896, pp. 188-199.

The tributaries of Milk River are for the most part intermittent streams, but the drainage ways contain local water pockets and a few springs which afford watering places for stock. As a rule this water is too alkaline for domestic purposes. The bench land is studded with numerous small intermittent lakes which occupy shallow depressions in the glacial drift. The water in these lakes, especially in the smaller ones, contains salts leached from the soil and is therefore alkaline.

The principal towns in the area are Havre, Chinook, Harlem, and Big Sandy. The first three are situated along the main line of the Great Northern Railway, which crosses the southern half of the field from east to west. Big Sandy is located in the southwestern part of the field, on the Montana Central division of the Great Northern Railway, which leaves the main line about 4 miles west of Havre and runs in a southwesterly direction to Great Falls and Helena.

GEOLOGY.

STRATIGRAPHY.

The sedimentary rocks outcropping in the part of the Milk River coal field under discussion consist mainly of sandstone and shale which belong to the Montana group of the Cretaceous system with the exception of a small infaulted area of Tertiary rocks about 6½ miles east of Big Sandy. These rocks are largely covered by glacial materials on the bench-land areas and by alluvial deposits in the larger valleys. In a few places they are cut by igneous intrusions or covered by lava flows.

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[a] Op. cit., pp. 38-39.

The following formations, which are given in ascending order, outcrop in this field: Eagle sandstone, Claggett formation, Judith River formation, Bearpaw shale, and Fort Union formation.

Stratigraphy of the Milk River coal field, Montana.

System.	Group or formation.	Thickness.	Description.
		Feet.	
Quaternary			Alluvial deposits. Glacial drift.
Tertiary	Fort Union formation		Massive gray to buff sandstone and thin beds of gray shale, with lignite beds.
(Fault.)			
Cretaceous	Montana group:		
	Bearpaw shale	80-100	Leaden-gray shale, with thin beds of sandstone and large concretions.
	Judith River formation	480	Alternating beds of light-colored sandstone, shale, and lignite.
	Claggett formation	350	Dark gray shales, with thin beds of buff sandstone near top and bottom.
	Eagle sandstone	250+	Massive to calcareous white to cream-colored sandstone, locally cross bedded; at top dark-gray shale, with intercalated beds of gray to buff sandstone.

UPPER CRETACEOUS ROCKS (MONTANA GROUP).

EAGLE SANDSTONE.

The **Eagle sandstone**, which is the lowest formation in the Montana group, outcrops along Missouri River and several of its tributaries in the extreme southwestern portion of the field. The basal member of this formation is a massive, calcareous, white to cream-colored, persistent, usually hard, and locally cross-bedded sandstone about 100 feet thick. Wherever the base of the Eagle is exposed it constitutes a horizon marker that is easily recognized. In the top 30 feet of the sandstone are numerous concretionary hard lenses of sandstone, some of which are highly stained by iron. These harder parts resist the effect of weathering much better than the rest of the sandstone and stand out as prominent knobs or cap thin rounded or angular spires of the underlying softer material. In places the entire massive stratum forms a steep cliff several miles in length and about 100 feet in height.

The upper member of the Eagle sandstone, which has a thickness of about 150 feet, is easily separable from the lower by its marked lithologic and topographic differences. The sandstone strata in this part of the formation are thin and more friable than those in the lower member. Sandy shales and carbonaceous layers with streaks of coal predominate in the lower half, but the upper half is principally dark-gray shale with a few intercalated beds of gray to buff sandstone. The line between the two members of the Eagle is very pronounced. Overlying the massive white ledge of sandstone are a number of coaly beds and carbonaceous shales which give this zone a dark color. The upper member, being much softer than the lower member, weathers into long, rounded slopes. Coal beds 6 to 8 inches in thickness were observed, but the greater part of the carbonaceous matter consists of black shale interbedded with fine laminæ of coal.

CLAGGETT FORMATION.

The Claggett formation, which consists largely of dark leaden-gray shales intercalated with thin beds of buff sandstone near the top and bottom, overlies the Eagle conformably. It is very similar lithologically to the Bearpaw shale, from which, without the aid of stratigraphic or paleontologic evidence, it is often distinguished with difficulty.

Gypsum flakes or crystals are scattered throughout this soft shale. Hard concretions of different sizes up to several feet in diameter are numerous, especially near the top. The concretions are calcareous and are usually traversed in all directions by cracks filled with amber-colored calcite or gypsum crystals. Invertebrates are found in the shale but more often in the calcareous concretions; however, they are not so abundant in this formation as in the Bearpaw shale. (See p. 84.) No coal occurs in this formation, but some thin carbonaceous shale was observed near the top. The Claggett in this field has an estimated thickness of 350 feet.

JUDITH RIVER FORMATION.

The Judith River formation overlies the Claggett conformably and is composed of alternating light-colored beds of sandstone and shale. It is almost entirely a fresh-water formation but some brackish-water beds are included at the top in the transition zone between the Judith River and the marine Bearpaw shale and at the base in the transition from the marine Claggett to the fresh-water Judith River formation. There is no persistent member in the entire formation which can be followed for any great distance. The ash-colored sandstone is locally cross-bedded and contains iron-stained concretionary bands. In some places the sandstone is hard and massive; in others it is soft and friable. The shales, sandstones, and coals of this formation are very lenticular and it is common to find a massive sandstone grading into a soft shale or a sandstone or shale grading into a carbonaceous shale or thin coal bed within a comparatively short distance horizontally. In the same manner a coal bed which consists of clean coal of workable thickness may pinch out altogether and be replaced by a sandstone at the next exposure half a mile away. A coal bed from 1 to 12 inches in thickness was observed in the base of the Judith River, but the coals of workable thickness occur within the upper 150 feet of the formation.

This formation outcrops extensively along Milk River northwest of Havre and near the mouth of Boxelder Creek in T. 32 N., R. 17 E., where intense erosion has carved it into typical badland forms. It has a total thickness of about 480 feet.

BEARPAW SHALE.

The Bearpaw shale overlies the Judith River formation conformably and consists of dark leaden-gray shale containing thin beds of sandstone and large concretions, many of which are highly fossiliferous. These round and oval bodies are fissured and the cracks are usually occupied by crystalline calcite. Selenite or gypsum flakes are scattered throughout the formation.

As previously stated, the Bearpaw and Claggett are very similar lithologically. Both are leaden gray in color, both contain similar concretionary masses and thin beds of sandstone and both weather into long, rounded slopes and form barren patches of loose weathered shale. The Bearpaw, which is represented by observed outcrops 80 to 100 feet in thickness in this field, has a known thickness of 350 to 900 feet in other parts of Montana.

TERTIARY SYSTEM (FORT UNION FORMATION).

Abundant fossil plants which are, according to F. H. Knowlton, of Fort Union age, were collected in sec. 18, T. 28 N., R. 14 E., about 6½ miles east of Big Sandy. These leaves occur above and below the coal beds in this district. The Fort Union outcrops in the western foothills of the Bearpaw Mountains, where it covers only a small area. From the few outcrops noted it was impossible to determine which part of the formation is present in this field, but it may possibly correspond to the upper yellow beds of the formation as developed in northeastern Montana and northwestern North Dakota.

Lithologically the Fort Union is notably different from the Judith River formation; it consists largely of massive strata of gray to buff sandstone, which are very persistent, and of thin beds of gray shale. These strata contain several beds of good coal which are discussed elsewhere in this paper. The position of this formation in the geologic column is several hundred feet above the Cretaceous formations already described, and its occurrence in this district is due to a fault having an estimated throw of about 2,000 feet.

GLACIAL AND ALLUVIAL DEPOSITS.

Among the features which should be fully described in any complete account of the region are several types of glacial and alluvial deposits, such as ground and recessional moraines, kames, eskers, drift, till, and river and lake deposits, which cover the greater part of the area. These features of recent glaciation and erosion can be only mentioned here.

IGNEOUS ROCKS.

In the area under consideration igneous rocks are comparatively rare, but a few prominent buttes are present in the vicinity of Havre and in the southwestern part of the field. The igneous rocks, which are of post-Eocene age, include both extrusive and intrusive types and have had little or no effect on the coal.

STRUCTURE.

As the area is largely covered by glacial and alluvial deposits and continuous exposures for great distances are lacking, the structure is very obscure. Except in a few places where the glacial cover is extremely thin, the only outcrops present in the field are along the lines of drainage where erosion has removed the glacial mantle. At these places the sedimentary rocks outcrop in small patches or long, narrow strips on either side of the coulées and along well-drained slopes. These rocks, which were originally approximately horizontal, have been subsequently disturbed by numerous faults and folds, which make the working out of the stratigraphy rather difficult. A vivid idea of the abundance of these disturbances is given by Hayden,[a] as follows:

> The most remarkable feature of this basin is the wonderful disturbance of the strata. So much are the beds disturbed and blended together by forces acting from beneath that it seems almost hopeless to obtain a section showing with perfect accuracy the order of superposition of the different strata.

The faults of the Milk River field are too numerous to be described individually. They are in general closely associated with folds and for the most part are of the thrust type, although a few normal or tension faults were observed. The faulting is best developed in the regions where the folding has been greatest. The larger thrust faults were probably developed at about the same time as the folds with which they are associated, and with one or two exceptions they are in a general way parallel to the axis of the Bearpaw Mountains.

The disturbances mentioned have caused lateral and vertical offsets of the coal beds, in many places tilting them to high angles.

THE COAL.

GENERAL STATEMENT.

All the coals in the Milk River field, so far as studied, may be classed as a fair grade of subbituminous coal ("black lignite"). Most of the coal beds are lenticular in shape, showing a variation in thickness from a fraction of an inch to 9 feet at different points on the outcrop. These beds are noticeably thinner and of a lower grade in the eastern part of the field than in the western part, so that beds of considerable thickness and good quality in the vicinity of Havre contain little or no coal near Harlem. Generally there is one bed, in some localities two, and in others four beds, all of workable thickness. The greater part of the coal of workable thickness occurs in the upper part of the Judith River formation (Upper Cretaceous), from 10 to 150 feet below the base of the Bearpaw shale, the only exception being the coal east of Big Sandy, which is of Fort Union (Tertiary) age.

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[a] Hayden, F. V., Proc. Acad. Nat. Sci. Philadelphia, 1857, p. 116.

On account of the small number of mines and prospects in the area it was necessary to study the coal largely from the weathered outcrops of the beds and from the data thus obtained to infer the character of the coal. The method employed in pursuing this study may be outlined briefly as follows. A careful search was made in coulées and ravines over the whole area for outcrops of coal beds. All coals thus found were traced by foot traverse until they pinched out, were covered by glacial or alluvial material, or were cut out by faults. All mines and prospects visited and all coal outcrops traversed were platted upon a topographic base prepared by the United States Geological Survey and all the coal beds were measured. Samples for chemical analysis were taken from the principal beds at the mines and prospects throughout the area. The examination showed that the topographic maps were well tied to the land surveys, and the section corners were so well marked that no difficulty was experienced in locating a corner when it was desired to tie a coal crop or prospect to a known point. The extensive glacial and alluvial covering in this field or the slumping of talus obscures the outcrop of coal over large areas, making the continuous tracing of coal beds or formation boundaries impossible.

In many places the coal beds and carbonaceous shale have been burned along the outcrop and the adjacent rocks have been baked to a red material resembling brick or tile. Prospects driven through the burned areas where the covering is from 20 to 50 feet thick demonstrated that it extends from 30 to 70 feet from the present outcrop of the hardened clinker and ash, and that the good coal bed continues behind the burned crops. The map (Pl. VI) shows the location of the coal zone, mines, and prospects with relation to the section corners, and such other geologic data relating to the coal as the scale of publication permits.

DETAILED DESCRIPTIONS.

For convenience the parts of the Milk River coal field with which the present report is concerned will be discussed as separate units termed the Havre, Chinook, Harlem, and Big Sandy districts. The boundaries of these districts have been arbitrarily chosen with reference only to the towns near which the greatest amount of mining is being carried on and from which coal shipments can be made.

HAVRE DISTRICT.

The Havre district is the best known in the Milk River field, on account of the local demand for the fuel and the fact that the largest coal mine in the area is located within its borders. This district as here treated embraces all of Tps. 32 to 34 N., Rs. 14 to 17 E., inclusive, and the northern tier of sections of T. 31 N., R. 17 E. Future work in this field will extend the boundaries of the Havre district both to the north and south of the area herein described. The coal of the district is as accessible as any other in the region and is easily reached by wagon roads which traverse the area in all directions. The sections given in the following pages show the thickness and contents of a few of the principal coal beds exposed at various localities throughout the field.

Locality 1:[a] The following section was measured in a prospect opened by Mr. Cowen in 1898 and worked during the winter of 1907 by Mr. Schean:

Section of coal bed in prospect in SE. ¼ NE. ¼ sec. 28, T. 33 N., R. 14 E. (No. 1).

	Ft.	In.
Shale, carbonaceous	2	3
Coal	3	
Bone and clay	1	5
Coal		4
Bone		3
Total coal	3	4

This bed was sampled at the breast of the workings about 75 feet from the mouth of the entry, where the coal showed little or no effect of slacking. The main coal has a bright black luster, is solid, and has a semiconchoidal fracture. On exposure to the air it loses moisture rapidly and checks or disintegrates into small irregular bits. The prospect is located about 30 feet southeast of a small fault which cuts the coal out to the northwest. Another small fault about 60 feet southeast of the opening limits the outcrop of the bed in that direction.

At the head of Supenau Coulee, in sec. 1, T. 33 N., R. 14 E., the coal zone of the Judith River formation is again exposed. Here the beds have a low dip to the northeast, which shows that the area to the north is underlain by the coal bed, while that south of the coal crop in the northern part of sec. 12, T. 33 N., R. 14 E., is probably not underlain by coal. On account of poor exposures no measurements were made of the coal at this place.

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[a] Numbers like this correspond to those on Pl. VI.

Locality 2: The following section was measured on the south side of Redrock Coulee, where a bed of coal which lies almost flat and under thin cover outcrops for a short distance. This coal is badly weathered but shows good cubical joints, indicating that it would probably prove to be of good quality. Redrock Coulee derives its name from the red rocks along the burned coal crops in T. 33 N., R. 17 E.

Section of rocks exposed in SE. ¼ sec. 10, T. 34 N., R. 15 E. (No. 2).

	Ft.	in.
Glacial deposits	17	
Shale, carbonaceous	2	
Bone	1	
Coal	2	6

Locality 3: The following section was measured near an abandoned prospect in sec. 7, T. 33 N., R. 15 E. The bed dips slightly to the northeast and probably underlies the greater part of the area between this point and locality 2.

Section of coal in SE. ¼ sec. 7, T. 33 N., R. 15 E. (No. 3).

	Ft.	in.
Glacial drift	10	
Coal	1	4
Shale, carbonaceous	1	
Coal	1	6
Bone		8
Bone with coaly streaks	2	6
Total coal	2	10

Locality 4: The character of the bed in the southeastern part of T. 33 N., R. 15 E., is represented in the following section, which was measured at an abandoned prospect in sec. 25:

Section of coal bed at prospect in NW. ¼ sec. 25, T. 33 N., R. 15 E. (No. 4).

	Ft.	in.
Shale, carbonaceous.		
Bone	1	6
Shale, carbonaceous		3
Coal, clean	3	
Bone		3
Shale, soft gray		5
Coal, rather bony	1	4
Bone.		
Total coal	4	4

This zone continues in a southeast direction under the glacial drift and is next exposed in sec. 31, T. 33 N., R. 16 E., south of the Havre Fuel Company's mine. It will be described under locality 8.

Locality 5: The following section was measured in a prospect located in the southwestern part of T. 33 N., R. 15 E., where the coal outcrops south of a thrust fault. This prospect, which was opened by H. Barrott, is worked by the room and pillar method. The main entry is about 250 feet long and follows the dip of the bed, which is about 8° NE. at this place.

Section at Barrott's prospect in SW. ¼ sec. 29, T. 33 N., R. 15 E. (No. 5.)

	Ft.	in.
Clay, shaly.		
Shale, carbonaceous	2	6
Coal		8
Bone		4
Shale, carbonaceous	4	
Coal		2
Bone		7
Coal	3	3
Total coal	4	1

The sample of coal which was taken from the 3-foot 3-inch bench of the above bed gave a calorific value of 8,944 British thermal units in the air-dried state.

Locality 6: The coal zone of the Judith River formation outcrops at various places in the bed of Coal Creek in the northern tier of sections of T. 33 N., R. 16 E. Here the beds, which dip about 3° NE., lie under very little cover and are badly weathered along the outcrop. The best exposure is at locality 6, in the SE. ¼ sec. 2, on the south bank of the creek. The following section represents the character of strata exposed at this point:

Section of rocks exposed in SE. ¼ sec. 2, T. 33 N., R. 16 E. (No. 6).

	Ft.	in.
Glacial drift	4	
Sandstone, clayey soft	3	
Shale, carbonaceous		2
Bone		4
Shale, sandy, carbonaceous	3	6
Coal		5
Bone		7
Coal	1	9
Clay, sandy, white		2
Coal	1	6
Shale, sandy, carbonaceous	1	8
Shale, drab	5	
Coal		11
Bone		4
Coal	1	2
Bone, with coaly streaks	1	9
Bone		4
Coal		11
Bone		5
Shale, black, carbonaceous.		
Total coal	6	8

Although the coal is badly weathered, it has well-developed cubical joints even at the surface, and by very little digging fresh coal of bright luster was uncovered, indicating that good coal exists within easy reach of the surface or within a short distance from the present outcrop. The coal extends beneath the glacial drift to the south, where it outcrops along the north side of a small coulee in secs. 28 and 29, T. 33 N., R. 16 E. At this place the coal contains numerous partings of bone and lies nearly flat under thin cover. Prospects have been driven at the head of the coulee in the N. ½ sec. 29, where the thickest bed contains three benches of coal 14, 16, and 17 inches thick, separated by 6 and 8 inches of bone. It is reported that these prospects were abandoned on account of the large amount of bone which could not be economically separated from the coal. From this point the bed swings to the southeast and then to the west around the head of a coulée at the Alcott and Gussenhoven prospects.

Locality 7: The following section down the slope of the Alcott prospect shows the coal content of the beds measured:

Section down the slope of the Alcott prospect in NW. ¼ SW. ¼ sec. 29, T. 33 N., R. 16 E. (No. 7).

	Ft.	in.
Glacial drift.		
Shale, carbonaceous		8
Coal		4
Shale, carbonaceous		9
Shale, sandy	7	10
Shale, brown, carbonaceous		1½
Shale, black, carbonaceous		½
Bone, with coaly layers		4
Coal		10
Bone		3
Shale, with thin coaly layers		7
Shale, gray	3	
Shale, carbonaceous		3
Coal	1	2
Bone, with thin coaly layers		2
Shale, carbonaceous		5½
Clay, ash-colored	2	10
Shale, carbonaceous		3
Coal, with thin bone seams		5
Bone		¼
Coal		6
Bone		1½
Coal		8
Bone		10
Coal	2	2½
Bone, with thin coaly layers	1	2
Clay		4
Bone		4½
Bone, with thin coaly layers		10
Total coal	6	1½

The lower 5½ feet of the above section is being worked in this prospect. The 2-foot 2½-inch bench is clean coal of bright luster, with well-developed cubical joints and a calorific value of 9,729 British thermal units on the air-dried sample. The area between the Alcott prospect and the Havre Fuel Company's mine is underlain by this bed.

Locality 8: The following sections were measured at different points in the workings of the Havre Fuel Company's mine in the NW. ¼ sec. 31, T. 33 N., R. 16 E., and show the variations in the same bed within a comparatively short distance:

Sections of coal bed in Havre Fuel Company's mine, NW. ¼ sec. 31, T. 33 N., R. 16 E. (No. 8).

	Ft.	in.
Roof, coal	1±	
Coal		9
Bone		5
Coal	1	5
Bone		2
Coal		11
Bone		10
Coal		8–10
Floor, shale, black, carbonaceous.		
Total coal	4 9 to 4	11

	Ft.	in.
Roof, shale, with thin coaly layers	1	4
Bone		2
Coal		9
Bone, with thin coaly layers		10
Bone		6
Coal	2	6
Bone		6
Coal		4–8
Floor, shale, carbonaceous.		
Total coal	3 7 to 3	11

A number of other sections measured in this mine show the coal and bone to be variable throughout the workings. In several places the bed consists almost entirely of bone with thin seams of coal; in others the clean coal predominates and is from 25 to 34 inches thick. The mine is the largest in the Milk River field, having underground workings about 2 miles long, as shown on the mine maps of the company. The mine workings lie under about 72 feet of cover, and according to information received from the foreman there are two coal beds above the one that is now being worked; one, about 10 feet above the workings, has a thickness of 2 to 2½ feet, and the other, about 25 feet above the workings, has a thickness of 8 to 10 inches. Both beds probably contain bony and shaly streaks.

From the data given under localities 2, 3, 4, 6, 7, and 8 it is evident that the area between these points is probably underlain by beds of coal, some of which are possibly of workable thickness and fair quality.

Locality 9: The dip of the coal bed in the prospect where the following section was measured is about 10° S. 40° W. This high dip is due to several small faults in the immediate vicinity.

Section of coal bed in a prospect in the SW. ¼ sec. 29, T. 32 N., R. 16 E. (No. 9).

	Ft.	In.
Roof, shale, gray.		
Coal	1	10
Bone, with coaly streaks	2	4
Coal	2	2
Floor shale.		
Total coal	4	

Locality 10: The following section was measured in an abandoned prospect northwest of Brown's prospect, in sec. 21, T. 32 N., R. 17 E.

Section of coal bed in old prospect in the SE. ¼ NE. ¼ sec. 21, T. 32 N., R. 17 E. (No. 10).

	Ft.	In.
Shale, buff, sandy.		
Coal, clean	1	2
Bone		3
Coal, clean	3	4
Bone		2
Coal, clean		5
Total coal	4	11

At one place in this prospect 45 inches of clean coal was measured. At the Brown prospect, less than one-quarter mile southeast of locality 10, this bed of coal contains numerous partings of bone, showing that the coal is not persistently clean for even short distances along the outcrop.

Coal belonging to the same zone outcrops at various places along Boxelder Creek and at the heads of coulées in secs. 1, 9, 10, and 11, T. 32 N., R. 17 E. The section of the bed is, however, very changeable. The beds in the northern part of the township are thinner and contain more partings of bone than those at locality 10, and the same may be said of the area southeast of the point where the section was measured.

Locality 11: The following section was measured in the Clack prospect, in the NE. ¼ sec. 5, T. 31 N., R. 17 E.

Section of coal bed in Clack prospect, NE. ¼ sec. 5, T. 31 N., R. 17 E. (No. 11).

	Ft.	In.
Roof, coal	1±	
Coal	2	8
Bone	1	
Coal	1	6
Floor, bone.		
Total coal	4	2

In working the above bed the 1-foot bone is mined out, then the coal is loosened by firing shots first in the bottom and then in the top bench of coal. In this way large lumps are obtained. The coal is of good quality and represents the same zone as that exposed in the Staton mine about 1 mile east of this point.

Locality 12: The following section measured in the Staton mine shows the character of the bed, which probably underlies the larger part of the southern tier of sections in T. 32 N., R. 17 E., and the two northern tiers of sections in T. 31 N., R. 17 E.

Section of Staton coal bed in NE. ¼ sec. 4, T. 31 N., R. 17 E. (No. 12).

	Ft.	In.
Roof, coal	1±	
Coal	3	1
Bone		10
Coal	1	10½
Total coal	4	11½

The coal zone outcropping in Tps. 33 and 34 N., R. 17 E., consists of very poor carbonaceous shale and bone containing many thin, coaly layers. In several places this bituminous shale and bone has burned along the outcrop. No coals of notable thickness were observed in this part of the field.

CHINOOK DISTRICT.

The Chinook district joins the Havre district on the east and embraces Tps. 32 to 34 N., Rs. 18 to 20 E., inclusive. Only a part of the district has been examined, and further field work will extend the boundaries to the north and south. The coal is easily reached by wagon roads leading in all directions across the bench land from the towns and ranches.

Locality 13: The following section was measured on the West Fork of Milk River, 1 mile northwest of Reser's ranch.

Section in the NW. ¼ SW. ¼ sec. 2, T. 34 N., R. 18 E. (No. 13).

	Ft.	In.
Shale, brown, carbonaceous.		
Coal, with thin, bony layers	3	6
Shale, brown, carbonaceous	1	4
Bone, with thin, coaly layers	2	8
Coal		3
Bone, with thin, coaly layers	1	5
Covered.		
Total coal	3	9

This bed is exposed on the north side of West Fork of Milk River south of a fault line. The dip at the outcrop is about 60° S., decreasing rapidly away from the disturbed zone. The Judith River formation is overlain by the Bearpaw shale south of the outcrop, giving the coal a good cover. That the eastern part of T. 34 N., R. 18 E., is underlain by workable beds is indicated by outcrops of the Bearpaw shale, which overlies coal at localities 13 and 14. In the southern part of the township the coal is not well developed. Here the beds resemble those in T. 33 N., R. 17 E., of the Havre district and consist mostly of carbonaceous shale and bone with thin coal seams.

Locality 14: The following section shows the character of the coal exposed in the McLelland prospect:

Section at the McLelland prospect, NW. ¼ sec. 12, T. 33 N., R. 18 E. (No. 14).

	Ft.	in.
Bone, with thin coal lenses	1	
Coal, with thin, bony streaks	2	4
Bone		4
Coal		6
Bone		5
Total coal, about	2	10

From the McLelland prospect the coal is traceable southeastward for about 1½ miles, to a point where it again disappears beneath the glacial drift.

The greater part of T. 33 N., R. 18 E., is occupied by valley wash, and as the coal-bearing formation has been eroded the land is important only for agricultural purposes. In the northwestern part of T. 32 N., R. 18 E., the coal zone outcrops along a coulée, but no beds of importance were observed. The zone is again exposed along Clear Creek in the same township. The thickest coal measured along this creek is 2 feet 8 inches thick.

Locality 15: The following section was measured at the Burns prospect, about a mile east of Clear Creek, and shows the character of the coal which probably underlies the area between the two places.

Section at Burns prospect, NW. ¼ sec. 11, T. 32 N., R. 18 E. (No. 15).

	Ft.	in.
Glacial drift.		
Shale, carbonaceous	1	
Coal		4
Shale, sandy, carbonaceous	3	
Shale, carbonaceous	3	6
Bone		4
Coal	3	
Total coal	3	4

The structure in T. 34 N., R. 19 E., is complicated by numerous faults, large and small, and as the coal crops can not be traced for any great distance, the sections given represent purely local conditions.

However, it is reasonable to suppose that wherever the Bearpaw outcrops in this township the area is underlain by workable beds similar to those given under localities 16 and 17.

Locality 16: The following section was measured on the south bank of the West Fork of Milk River at the Leabo prospect, in sec. 29, T. 34 N., R. 19 E.

Section at Leabo prospect, SW. ¼ sec. 29, T. 34 N., R. 19 E. (No. 16).

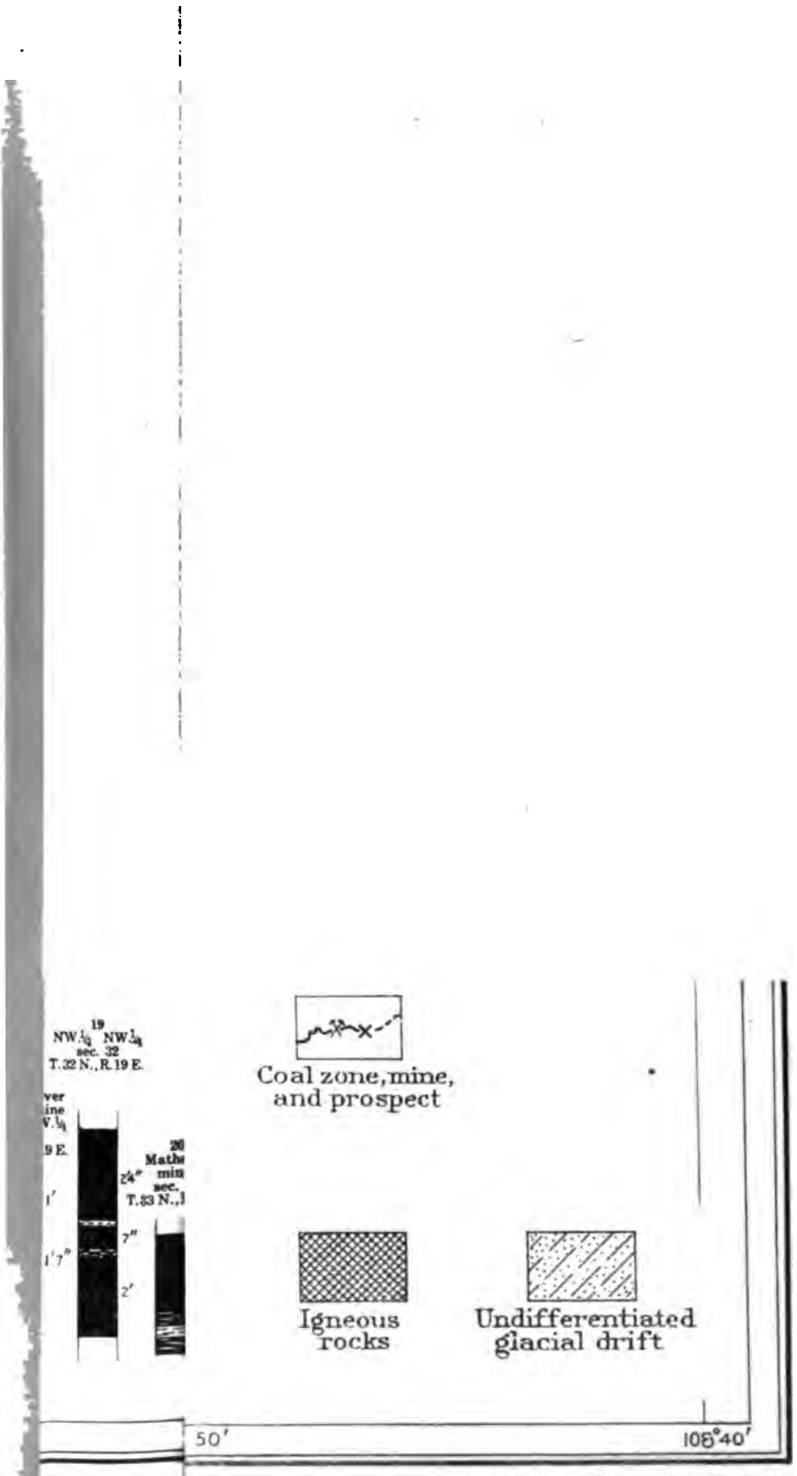
	Ft.	In.
Glacial drift	10	
Shale, carbonaceous	3	
Coal, rather bony	1	6
Shale, carbonaceous	1	4
Shale, sandy	9	
Shale and thin sandstone	16	
Coal, rather bony	3	6
Clay, sandy	5	
Coal		8
Bone	1	
Coal, same as in Leabo prospect	3	4
Covered	10	
Coal exposed in bed of West Fork, partly covered by water	4	
Total coal about	13	

The outcrop of this coal bed continues southeastward and then westward beneath the glacial cover and connects with the bed exposed at the Milk River Coal Company's mine (locality 18).

Locality 17: The character of the coal underlying the eastern half of T. 34 N., R. 19 E., is shown in the following section:

Section of rocks near center of sec. 23, T. 34 N., R. 19 E. (No. 17).

	Ft.	In.
Glacial drift	5	
Shale, carbonaceous	1	
Coal	3±	
Shale, carbonaceous	2	
Coal	3±	
Shale	6	
Shale with coaly bands	7	
Clay, sandy	2	
Shale, carbonaceous		2
Coal with thin bony streaks	1	3
Shale, carbonaceous	2	
Covered.		
Total coal	7	3±



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Locality 18: The following section measured in the Milk River Coal Company's mine shows the character of the bed worked at this place. Besides the bed worked by the company there are two beds containing from 2½ to 4 feet of coal and bone in the same locality. The bone content is variable.

Section of coal bed in Milk River Coal Company's mine, NW. ¼ NW. ¼ sec. 18, T. 33 N., R. 19 E. (No. 18).

	Ft.	In.
Bone, with coal streaks:		
Coal	1	
Clay		2
Coal	1	7
Bone	1	2
Coal[a]	2	6
Shale, carbonaceous.		
Total coal	5	1

The coal outcropping in the northeast quarter of T. 33 N., R. 19 E., has been disturbed by faults. In many places it has burned out. No good exposures were discovered, but there are probably coal beds from 2 to 3 feet thick.

Locality 19: The following section measured at the Tumbler prospect shows the character of the coal outcropping in T. 33 N., R. 19 E. The beds in this township have been distorted in many places by faults, consequently it is impossible to trace a single bed for any great distance, even where the rocks are well exposed.

Section of coal bed in the Tumbler prospect, NW. ¼ NW. ¼ sec. 32, T. 32 N., R. 19 E. (No. 19).

	Ft.	In.
Coal	2	4
Bone		1½
Coal		7½
Bone		3
Coal	2	
Total coal	4	11½

The coal beds outcropping in T. 34 N., R. 20 E., are unimportant and may be dismissed without further comment. It should be borne in mind, however, that workable beds, which do not outcrop within the township, may underlie it.

Locality 20: In the NE. ¼ SW. ¼ sec. 10, T. 33 N., R. 20 E., a coal bed is brought to the surface by a fault which has a northwest-southeast trend. A small prospect known as the Matheson mine is located on this coal on the west side of Coal Coulee southwest of the fault line. The following section was measured at the mouth of this prospect.

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[a] This bench has been unintentionally omitted in the graphic section (No. 18, Pl. VI)

Section at Matheson prospect, NE. ¼ SW. ¼ sec. 10, T. 33 N., R. 20 E. (No. 20).

	Ft.	in.
Coal	1	2
Shale, carbonaceous		4
Shale, sandy carbonaceous	1	2
Coal	2	
Bone		4
Coal	1	
Bone		6
Clay, sandy		1
Coal	1	
Bone	1	
Shale, carbonaceous	2	
Total coal	5	2

This is the only important bed which outcrops in the township. The coal bed mapped in the southern part of the township consists of carbonaceous shale and a thin bed of dirty coal 1 to 1½ feet in thickness.

A dirty bed of coal coresponding to the one just described, but having a thickness of about 2 feet 9 inches, outcrops in the eastern part of T. 32 N., R. 20 E. This bed contains little clean coal, but consists of alternating layers of bone, carbonaceous shale and mineral charcoal, and thin coaly layers. The cover is thin, and the bed is badly weathered along the outcrop.

Locality 21: The Judith River formation outcrops in the southwestern part of T. 32 N., R. 20 E., and is overlain by the Bearpaw shale. The strata show evidence of faults. The only coal of importance within the township outcrops along the Sixmile Coulee. The following section measured in the Kerr mine shows the character of this bed:

Section in Kerr's mine, N W. ¼ SW. ¼ sec. 30, T. 32 N., R. 20 E. (No. 21).

	Ft.	in.
Roof, shale, black, carbonaceous.		
Coal		6
Coal, bony		5
Coal, good	2	5
Floor, bone.		
Total coal	2	11

From the foregoing discussion it is evident that the coal zone, which contains good workable coals in the Havre district and the western two-thirds of the Chinook district, becomes poorer as a source of thick coals toward the east. The beds in the eastern part of the Chinook district are thinner, contain more bone, and are less persistent than those in the western part of the area discussed.

HARLEM DISTRICT.

The Harlem district is the least important in the part of the Milk River field under consideration. It joins the Chinook district on the east and embraces Tps. 32 to 34 N., Rs. 21 to 23 E., inclusive. As in the Havre and Chinook districts, only a part of the Harlem district was examined during the summer of 1908, and future field work will extend the boundaries to the north and south of the area described here. The coals gradually become thinner and of poorer quality from west to east in this district, and with few exceptions the beds consist largely of bony coal under thin cover and consequently of low value as a fuel. Owing to the scarcity of wood in the district it has been necessary to work beds of coal which, in other localities, would be considered almost worthless at the present time. The coal in the area is easily accessible by wagon roads from Harlem and the ranches in the district.

The thickest coal observed in T. 34 N., R. 21 E., is only 8 inches thick, consequently the coals outcropping in this township may be dismissed without further comment.

Locality 22: At a small prospect in the NE. ¼ sec. 26, T. 33 N., R. 21 E., the following section was measured. The bed at this locality has a dip of 40° N. 60° E., due to a northwest-southeast fault.

Section of coal bed at prospect in NE. ¼ sec. 26, T. 33 N., R. 21 E. (No. 22).

	Ft.	In.
Shale, brown carbonaceous		4
Coal, with numerous partings of sandstone and bone	3	6
Shale, carbonaceous with thin coaly layers.		

The coal of the above bed is pockety; in some places the clean coal is over a foot in thickness but only for short distances, making it necessary to remove large quantities of rock to procure a small amount of good coal.

Locality 23: The following section measured in unsurveyed sec. 9, T. 33 N., R. 22 E., at an abandoned prospect, shows the character of the coal along Thirtymile Creek:

Section at prospect in SW. ¼ sec. 9, T. 33 N., R. 22 E. (No. 23).

	Ft.	In.
Bearpaw shale	68±	
Sandstone, soft, gray	20	
Shale	10	
Shale, sandy	3±	
Coal	1	1
Bone		5½
Coal	1	
Bone.		
Total coal	2	1

A sample taken from this bed gave a calorific value of 8,568 British thermal units on the air-dried coal, showing that the fuel is of low grade. However, part of this low efficiency is due to the large amount of ash caused by the numerous bony layers in the bed.

The strata exposed along Thirtymile Creek have been disturbed by faults, making mining on the east side rather uncertain. The dips on the west side are more constant and the coal is under thicker cover, being overlain by the Bearpaw shale.

A coal bed containing many partings and having a thickness of about 2 feet 9 inches has been prospected in the NW. ¼ sec. 27, T. 33 N., R. 22 E., and a bed of similar content was worked in the SE. ¼ sec. 30, T. 32 N., R. 22 E., during the winter of 1907–8. Coal from the last-named prospect sold for $7.50 a ton delivered at Harlem, a distance of about 8 miles. From this statement it is evident that these low-grade coals have some value at the present time, especially during severe winters.

BIG SANDY DISTRICT.

The sketch map (fig. 2) shows the location of the two principal mines in the Big Sandy district. They are situated in sec. 18, T. 28 N., R. 14 E., about 6½ miles east by a little north of the town of Big Sandy, and are easily reached by wagon road from the town and ranches in the vicinity. These mines were visited at the close of the field season of 1908, when the coal beds were measured and sampled. As no detailed mapping of formations of coal beds was attempted at that time, the boundaries of the district were not determined. As previously stated, the coals of this area are of Fort Union (Tertiary) age and consequently are younger than those of the Judith River formation already described, which they overlie stratigraphically.

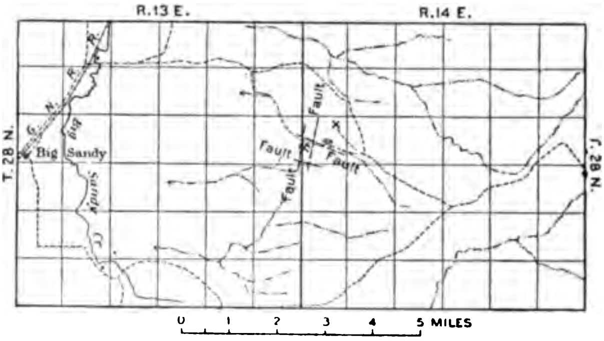

FIGURE 2.—Sketch map of Big Sandy district, Milk River coal field, Montana.

The following section shows the character of the beds exposed at the Mackton Coal Company's mine:

Section at the Mackton Coal Company's mine, NW. ¼ SW. ¼ sec. 18, T. 28 N., R. 14 E.

	Ft.	in.
Sandstone.		
Shale, sandy	2	
Coal	4	
Sandstone, buff, massive, intercalated with sandy gray shale	35±	
Shale, carbonaceous		1
Coal	2	5½
Bone, variable		2
Coal	1	3
Bone		7
Coal		6
Bone		4
Coal	3	11
Clay, gray.		
Total coal	12	1½

The following section was measured in the NW. ¼ SE. ¼ sec. 18, T. 28 N., R. 14 E., in the Mack mine. The bed is probably the same as the upper bed given in the preceding section.

Section of coal bed in Mack mine, NW. ¼ SE. ¼ sec. 18, T. 28 N., R. 14 E.

	Ft.	in.
Clay shale, gray	1	8
Shale, carbonaceous		2
Bone, variable		4
Coal		5
Bone with thin coaly streaks	2	4
Coal	4	6
Clay.		
Total coal	4	11

At the Mackton Coal Company's mine the strata dip about 40° E., indicating a north-south fault between this place and the Mack mine, where the strata lie practically flat. In the NE. ¼ sec. 18, T. 28 N., R. 14 E., a coal bed outcrops along a coulée and has been prospected in several places. The strata at this place also show evidence of faults. The Judith River formation in the vicinity of Big Sandy contains several very thin coals, but no bed of workable thickness was observed in this formation within the Big Sandy district.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

In studying the coals of the Milk River field an attempt was made to gather as many facts as possible concerning their physical properties, and the principal characteristics observed may be briefly summed up. The coal of the Havre, Chinook, and Harlem districts is in general pitch black to brownish black in color, the streak is dark brown the luster bright and sometimes waxy. Two systems of joints are usually present and the coal commonly splits also along the bedding planes. The fracture of the solid coal is semiconchoidal or irregular. Fresh samples are usually brittle, but sometimes tough. The texture varies from dense to woody. Thin incrustations of gypsum flakes in the form of selenite crystals occur between the joint and bedding planes, especially on the weathered outcrop. Some mineral charcoal, fossil resin, and, rarely, iron pyrites were observed.

The coal of the Big Sandy district is hard and brittle. Its fracture is principally conchoidal. It has a bright black luster and two systems of joint planes, one of which is better developed than the other. These beds are more regular than the other coals of the Milk River field; that is, in the small area examined the sandstone, shale, and coal beds seem in general to be persistent rather than lenticular.

CHEMICAL CHARACTER.

The composition of the coal of the Milk River field is shown by the following analyses: The samples from which these analyses were made were collected in conformity with the regulations of the United States Geological Survey and the chemical work was done under the direction of F. M. Stanton at the Pittsburg laboratory.

Analyses of coal samples from the Milk River field, Montana.

		Havre district.								
Location		NE. ¼ sec. 28, T.33 N., R. 14 E.	SW. ¼ sec. 29, T.33 N., R. 15 E.	NE. ¼ sec. 26, T.33 N., R. 15 E.	SW. ¼ sec. 29, T.33 N., R. 16 E.	NW. ¼ sec. 31, T.33 N., R. 16 E.	SE. ¼ sec. 30, T.32 N., R. 16 E.	E. ½ sec. 21, T.32 N., R. 17 E.	NE. ¼ sec. 5, T.31 N., R. 17 E.	NE. ¼ sec. 4, T.31 N., R. 17 E.
Laboratory sample No.		6549	6548	6475	6474	6479	6473	6477	6640	6478
Sample as received:										
Prox.	Moisture	21.24	21.51	21.07	24.12	21.96	22.84	18.97	25.59	29.19
	Volatile matter	31.44	29.28	30.00	26.58	23.80	29.31	27.05	27.96	26.67
	Fixed carbon	36.44	35.55	38.12	38.97	43.90	34.61	35.43	39.18	37.40
	Ash	10.88	13.66	10.81	10.33	10.34	13.24	18.55	7.27	6.74
Ult.	Sulphur	.87	.73	.75	.69	.60	.80	1.48	.58	.67
	Hydrogen					5.67			6.19	6.39
	Carbon					47.98			49.08	46.04
	Nitrogen					.99			1.03	.94
	Oxygen					34.42			35.85	39.22
Calories		4,580	4,363	4,676	4,540	4,563	4,388	4,153	4,607	4,353
British thermal units		8,244	7.853	8,417	8,172	8,213	7,898	7,475	8,293	7,835
Loss of moisture on air drying.		12.90	12.20	14.10	16.00	15.50	16.30	13.60	14.20	22.90
Air-dried sample:										
Prox.	Moisture	9.58	10.60	8.11	9.67	7.64	7.81	6.21	13.27	8.16
	Volatile matter	36.10	33.35	34.93	31.64	28.17	35.02	31.31	32.59	34.59
	Fixed carbon	41.83	40.49	44.37	46.39	51.95	41.35	41.01	45.67	48.51
	Ash	12.49	15.56	12.59	12.30	12.24	15.82	21.47	8.47	8.74
Ult.	Sulphur	1.00	.83	.87	.82	.71	.95	1.71	.68	.87
	Hydrogen					4.67			5.39	4.99
	Carbon					56.78			57.20	59.72
	Nitrogen					1.17			1.20	1.22
	Oxygen					24.43			27.06	24.46
Calories		5,258	4,969	5,444	5.405	5,400	5,243	4,807	5,370	5,646
British thermal units		9,464	8,944	9,799	9,729	9,720	9,437	8,653	9,666	10,163

Analyses of coal samples from the Milk River field, Montana—Continued.

Location	Chinook district.					Harlem district.	Big Sandy district.	
	SW. ¼ sec. 29, T. 34 N., R. 19 E.	NW. ¼ sec. 18, T. 33 N., R. 19 E.	NW. ¼ sec. 32, T. 32 N., R. 19 E.	SW. ¼ sec. 30, T. 32 N., R. 20 E.	SW. ¼ sec. 10, T. 33 N., R. 20 E.	SW. ¼ sec. 9, T. 33 N., R. 22 E.	SW. ¼ sec. 18, T. 28 N., R. 14 E.	SE. ¼ sec. 18, T. 28 N., R. 14 E.
Laboratory sample No.	6381	6316	6318	6317	6380	6315	6550	6609
Sample as received:								
Prox. Moisture	26.67	22.89	21.44	20.48	23.27	30.00	12.07	14.86
Volatile matter	26.41	28.76	26.59	28.81	29.87	40.10	34.71	34.58
Fixed carbon	40.02	39.32	41.14	39.27	33.12	18.00	41.68	44.20
Ash	6.90	9.03	10.83	11.44	13.74	11.90	11.54	6.36
Ult. Sulphur	.68	.56	.64	.81	.72	1.08	.80	.46
Hydrogen	6.09	....	5.73	....	5.80	5.53	5.30	5.41
Carbon	49.23	....	50.43	....	44.90	40.39	55.85	58.56
Nitrogen	.91	....	1.09	....	.89	.80	.71	.85
Oxygen	36.19	....	31.28	....	33.95	40.30	25.80	28.36
Calories	4,690	4,685	4,808	....	4,332	3,841	5,332	5,521
British thermal units	8,442	8,433	8,654	....	7,798	6,914	9,598	9,938
Loss of moisture on air drying	18.50	12.00	11.80	10.30	14.90	19.30	5.50	5.60
Air-dried sample:								
Prox. Moisture	10.02	12.38	10.93	11.35	9.83	13.26	6.95	9.81
Volatile matter	32.41	32.68	30.15	32.12	35.10	49.69	36.73	36.63
Fixed carbon	49.10	44.68	46.64	43.78	38.92	22.30	44.11	46.82
Ash	8.47	10.26	12.28	12.75	16.15	14.75	12.21	6.74
Ult. Sulphur	.83	.64	.73	.90	.85	1.34	.85	.49
Hydrogen	4.94	....	5.01	....	4.86	4.20	4.96	5.07
Carbon	60.41	....	57.18	....	52.76	50.05	59.10	62.03
Nitrogen	1.12	....	1.24	....	1.05	.99	.75	.90
Oxygen	24.23	....	23.56	....	24.33	28.67	22.13	24.77
Calories	5,755	5,324	5,451	....	5,090	4,760	5,642	5,848
British thermal units	10,359	9,583	9,821	....	9,162	8,568	10,156	10,526

A study of the analyses of coals from the Havre, Chinook, and Harlem districts shows that the Judith River coals of this field are comparatively low in sulphur and high in moisture and ash, though in some samples the amount of ash is only medium. The heating value of these coals, ranging from 8,568 to 10,359 British thermal units on air-dried samples, and their poor keeping quality indicate that they should be classed as subbituminous coals. The coals burn with a medium-long, orange-colored flame which is smoky under ordinary circumstances. The ash is fine and has a gray color.

The Fort Union coal from the Big Sandy district contains a lower percentage of moisture than those from the other districts, and consequently stocks to better advantage, as it tends to slack more slowly than coal containing high amounts of moisture. The amount of ash varies from medium to high, and the heating value from 10,156 to 10,526 British thermal units on air-dried samples. The coal is therefore subbituminous, but close to the bituminous grade.

The low heating value, the low specific gravity (about 1.3), the high percentage of volatile matter, and the low percentage of fixed carbon show the coals to be of value for gas-producer purposes and domestic and boiler use.

Two things are essential to insure the most economical results with fuel of this class when used under boilers. First, as the coal disintegrates rapidly on losing the large percentage of moisture which it contains, it is necessary to use a fine grate similar to the herringbone type in order to minimize the loss of coal passing through the grate bars. Second, a suitably high draft is necessary to insure perfect combustion.

QUANTITY OF COAL AVAILABLE.

It has been pointed out in the foregoing pages that the greater part of the field with which this report is concerned is covered by glacial and alluvial deposits and that the complex structure is greatly obscured by this covering. Consequently, at the present time it is difficult to estimate even approximately the total quantity of coal available in the region. Future demands for this grade of fuel may encourage detailed prospecting with the diamond drill, which will give the data necessary for estimating the tonnage of available coal.

CONDITIONS OF MINING AND TRANSPORTATION.

The largest and best-equipped mine in the field is that operated by the Havre Fuel Company, which has installed one of the most modern surface plants in the State. The cars are hauled in the workings of the mine by mules to the foot of the incline, where they are attached to a cable and drawn to the surface by steam power. From this place they are hauled by a 10-ton Baldwin Westinghouse electric locomotive to the tipple, about a mile southeast of the mine. Here they are weighed and automatically dumped, and the coal is loaded into box cars on a spur of the Great Northern Railway which has been built across Milk River from the main line of the railroad at Havre. The only other mine in the field having a steam surface plant is that of the Mackton Coal Company. At this mine the cars are brought to the surface by a steam hoist, dumped into a chute, and conveyed to bins, from which wagons are loaded. Coal from the Staton mine is hauled to Havre partly by wagon and partly by traction engine. A railroad line has been surveyed connecting this property with the main line of the Great Northern Railway at Havre, but as yet no grading has been done. The coal from the other mines in the field is transported by wagon.

The mines in the field employing the largest number of men are those of the Havre Fuel Company, 4 to 30; the Mackton Coal Company, 4 to 16; and the Staton Coal Company, 4 to 10. The other mines and prospects in the area employ from 1 to 3 men each.

The roof and floor in most of the mines and prospects in the field are soft sandstone or carbonaceous shale, making it necessary in most places to leave coal in the roof to keep the entries from caving in. Extensive timbering will be necessary when mining is done on a large scale, and this will add to the cost of producing coal, as there is no timber in the field suitable for stulls, lagging, or props.

FUTURE DEVELOPMENT.

As the coal of the Milk River field is high in moisture and slacks rapidly on exposure, it can not be shipped great distances in uncovered cars. The rapid disintegration of the coal when burned, together with its low specific gravity, make it a poor railroad fuel with engine grates of the present pattern and the strong draft of the locomotive, as much of the finely-divided coal would be lost through the grate bars and the stack. Consequently the future development of the area will depend largely on an increase in the population of Milk River valley. If the several large reclamation projects which are proposed in this general region are completed, the population will greatly increase and there will be a greater local demand for the fuel.

A few carload shipments have been made to Seattle and Spokane, Wash., and to Helena, Great Falls, and Conrad, Mont., but the greater part of production, which was 24,847 tons[a] in 1907, is consumed locally.

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[a] Mineral Resources U. S. for 1907, pt. 2, U. S. Geol. Survey, 1908, p. 50.

NOTES ON THE COALS OF THE CUSTER NATIONAL FOREST, MONTANA.

By Carroll H. Wegemann.

INTRODUCTION.

General situation.—The Custer National Forest, comprising an area of approximately 950 square miles, lies to the eastward of Tongue River in southeastern Montana, a little north of the Montana-Wyoming line. Its coal field is a part of the broad area of coal-bearing rocks of Eocene age, which extends from North Dakota across Montana far into Wyoming.

In the spring of 1908 it was the writer's privilege to accompany a small party from the Forest Service engaged in the examination of timber in this region. In working from the camps it was impracticable to trace individual coal beds from township to township over the area. Beds were traced in separated localities as time allowed, and for correlation recourse was had to detailed stratigraphic sections. Although data of this nature are sometimes misleading, the information gathered in the four weeks spent on the work was sufficient to warrant the classification of four townships in the northern part of the forest.

Relation to other fields.—The yellow beds of the Fort Union formation are the only rocks exposed within the area. They lie practically flat. To the north they are continuous with the rocks of the Miles City coal field;[a] to the south with the rocks of the Sheridan field of Wyoming.[b]

Routes of travel.—The post-office of Ashland, the home of the forest supervisor, is situated at the junction of Otter Creek with Tongue River and is reached by daily stage from Forsyth, 65 miles away. There is also a main road up Tongue River from Miles City which runs through to Sheridan, Wyo. Stacey post-office, on the northeast border of the forest, is reached by a stage road up Tongue River and Pumpkin Creek from Miles City. There is a good road up Otter Creek, and wagon roads follow most of the larger tributaries of the above-mentioned streams.

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[a] Collier, A. J., and Smith, C. D., The Miles City coal field, Montana: Bull. U. S. Geol. Survey No. 341, 1909, pp. 36-61.

[b] Taff, J. A., The Sheridan coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 123-150.

TOPOGRAPHY.

The topography may be discussed under three main heads, the lowlands, the badlands, and the uplands. Terraces occur along Tongue River, but they are of small extent.

The lowlands consist of the present river flood plains. They constitute the lands available for irrigation and are very fertile, alfalfa and oats being the principal crops.

Badlands are not as typically developed in the yellow beds of the Fort Union formation, which show little variation in texture and hardness, as in the alternating hard and soft rocks of the somber-colored beds which underlie them. They are present, however, in this area along certain streams—as, for example, Pumpkin Creek and its tributaries. Here they form a transition zone between the uplands, which are but little affected by erosion, and the river flats, which have been completely leveled. They represent, in fact, the maturely developed topography of the region, sharp ridges and deep canyon-like valleys alternating with one another in such rapid succession that travel across the drainage lines is often difficult.

The uplands rise in abrupt escarpments from the lower levels of the badlands or in places directly from the river flats. Their existence is due to the heavy beds of baked sandstone and shale formed by the burning of the coals of the region. These "slags" that cap or rim the uplands effectually retard the down-cutting of the streams which drain them and so protect the uplands from degradation. When the slag cap is once dissected and the soft rocks below are exposed to the conditions of erosion in an arid climate, badlands are formed, provided the main streams have sufficient gradient for rapid cutting and other heavy slag beds do not interrupt the work. Each heavy bed of slag determines an upland area. These may rise one above another in a series of benches to the high divides between the streams. Some of these benches are gently rolling, forming excellent grazing land, and in some places being suitable for "dry farming," or the raising of crops without irrigation. Many of the ridges rise 200 to 300 feet above the valley floors. The total thickness of rocks exposed from Tongue River to the crest of the divide is 1,200 feet.

Drainage.—The portion of the forest examined is drained by Tongue River and two of its larger tributaries, Otter and Pumpkin creeks. Tongue River, which follows the western border, rises in the Bighorn Mountains of Wyoming and flows northeastward to join the Yellowstone at Miles City, Mont. The Custer Forest is situated about halfway along its course. Otter Creek rises a little south of the forest and flows northward across it to unite with Tongue River at Ashland. Pumpkin Creek rises on the eastern border of the forest and flows northeastward parallel to Tongue River for a considerable distance; then turning northwesterly it joins the main stream about 12 miles above its mouth.

GEOLOGY.

Stratigraphy.—As has been stated, the only rocks exposed within the area are the yellow beds of the Fort Union formation, of early Eocene age. In the Miles City district the underlying dark shales of the somber-colored beds are also exposed, and the contact of the two may be traced as one rides up Tongue River. At a point a little below Coleman's ranch, about 10 miles north of Ashland, the somber-colored beds disappear beneath the river. The beds of the Fort Union formation are for the most part white and cream-colored shales and sandstones which present but slight variation in texture and color. At intervals occur thin beds of impure limestone which, being harder than the adjacent rocks, stand out in small ledges. Here and there thin beds of gray shale and of brown carbonaceous shale may be observed, but the beds most easily recognized in the section are the subbituminous coals and the slags formed by their burning. In fact, the coal beds furnish about the only means by which different portions of the section may be recognized.

About 400 feet above the base of the Fort Union formation appears a series of gray sandstones and shales approximately 100 feet in thickness. It contains numerous thin beds of ferruginous limestone which weather brown and red. The resemblance of this part of the Fort Union to the typical somber beds is striking. Whether or not these rocks are constant in character over any considerable area it is impossible to say. Their occurrence is probably of no great importance, simply showing that during the deposition of the Fort Union formation conditions recurred similar to those which prevailed while the somber-colored beds were being deposited.

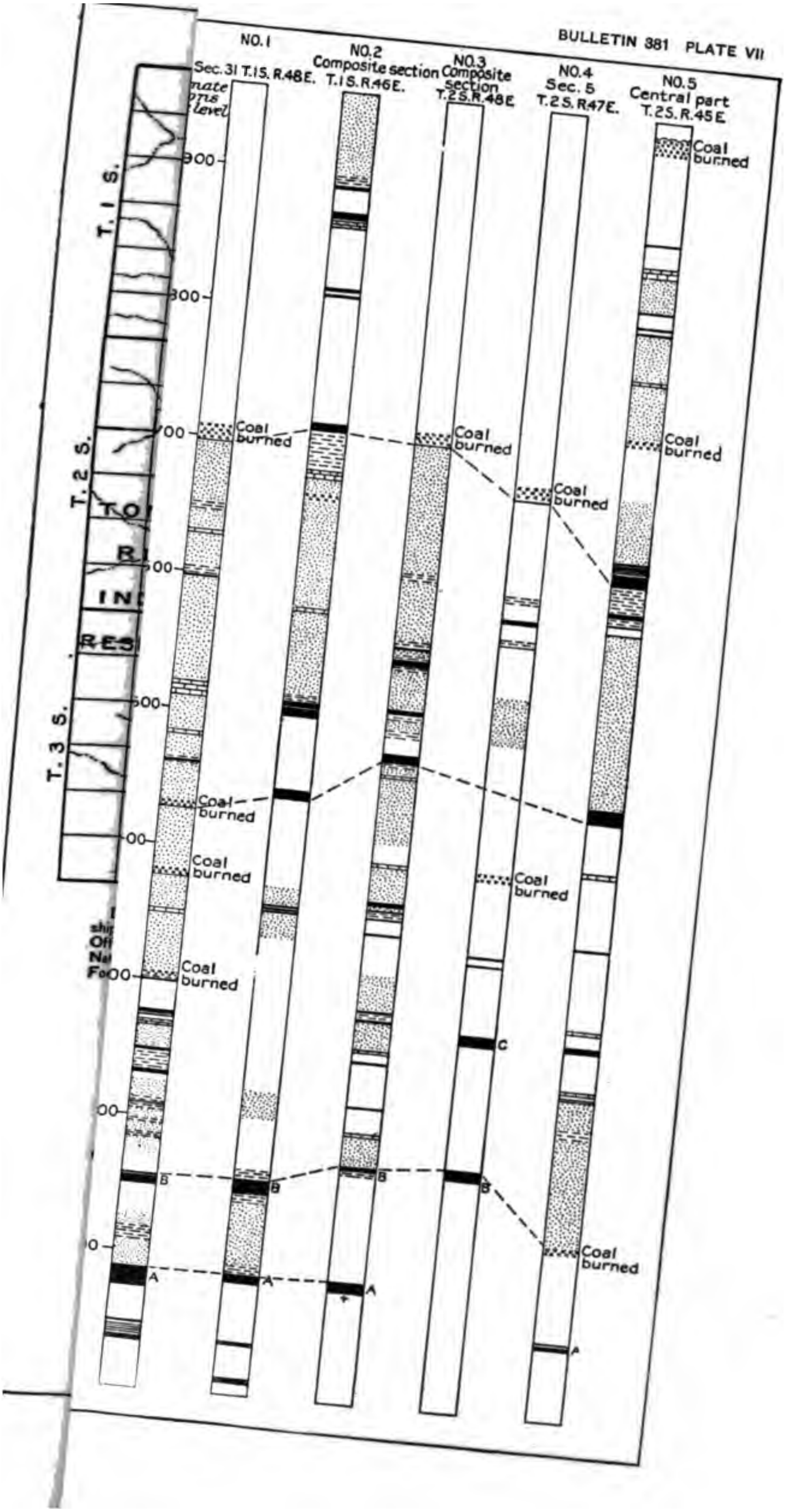
All these strata are of fresh-water origin. Many of the thin limestone layers contain fossil leaves, and in the dark shales just mentioned there are several thin beds rich in gastropod shells.

Structure.—So far as could be determined the rocks within the area are horizontal, the dips being too slight to be detected with the instruments employed.

COAL.

GENERAL DESCRIPTION.

Coal beds ranging from a few inches to many feet in thickness occur throughout the stratigraphic section in this region. They seem to be fairly constant in thickness and quality over considerable areas, but too much reliance should not be placed on this continuity, for shale seams appear in many places, rendering a coal valueless which at another locality is workable. Coal beds run out into bone or black shale or disappear altogether. On the other hand, if several exposures of good coal are found on the same bed at intervals of a mile or two, the bed appearing to be fairly constant in thickness and


NO. 1
Sec. 31 T.1S. R.48E.
NO. 2
Composite section T.1S. R.46E.
NO. 3
Composite section T.2S. R.48E.
NO. 4
Sec. 5 T.2S. R.47E.
NO. 5
Central part T.2S. R.45E.
900
800
700
600
500
400
Coal burned
A
B
C
T. 1 S.
T. 2 S.
T. 3 S.
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quality, it is very probable that the coal is good between the exposures, although it may be completely concealed.

Silicified logs were noted in many of the coal beds. Some of these logs appear as slabs representing but about one-third of the original trunk, the upper side being flat and the lower conforming to the shape of the original log. In some places the logs when partly decayed were undoubtedly crushed and flattened by the load above them, but it is possible that in others as the log lay in the bog the upper portion turned to coal while the lower under different conditions was silicified.

The coal of this field is somewhat darker than the Miles City lignite described by Collier. When first mined it has a brownish cast, but soon blackens on exposure. The grain of the original wood is for the most part well preserved, yet there are seams between the woody layers which have lost all woody structure. In them the coal is black and shiny with conchoidal fracture.

That the coal is subbituminous rather than lignite may be questioned. It lies near the border line between the two. On the whole, it resembles more the subbituminous coals of the Sheridan field than the lignites which occur east of Miles City, being darker than the latter and containing a greater amount of material in which no woody structure is apparent. The Sheridan coals run as high as 10,000 British thermal units in calorific value; the Miles City lignite runs about 8,200 British thermal units. No samples for analysis were obtained from the Custer Forest, yet an idea of the probable calorific value of the coal may be formed from the values in these adjoining fields.

DEVELOPMENT.

Mining development has made but slight progress in the Custer Forest. Coal is so plentiful that almost every ranch has its own bank, where the coal is obtained by stripping the surface and mining from the open face of the bed. No drift or shaft was seen by the writer, and until a railroad runs up the Tongue River valley the demand for coal must be but local.

DETAILED DESCRIPTIONS.

In the following descriptions the area is taken up by townships, beginning at the northeast corner of the field examined and passing from east to west.

T. 1 S., R. 48 E.—Two beds of good coal with an interval of about 60 feet between them are exposed along a coulée in the southwest corner of this township (Pl. VII, No. 1). The lower bed, which is 14 feet in thickness, has been worked to a moderate extent. The upper bed is about 7 feet thick. It has not been prospected at this locality, but about a mile to the southwest it has been mined. Both beds, like most of the coal of this region, have burned widely, forming marked "slag" horizons.

North of the Charles Daly ranch in section 18 coal is exposed in a hillside. The bed is at present so obscured by slumping that a measurement could not be obtained. It is stated, however, that this coal is of considerable thickness and was formerly mined. It is by barometer 110 feet below the 14-foot bed in the southwest corner of the township.

The coal outcrops in this township were not mapped. The coal area is probably confined, however, to the southwestern portion, as the beds described have been removed by erosion from the northern part of the township and the presence of lower workable coals is uncertain.

T. 1 S., R. 47 E.—Coal is mined for use at Stacey post-office in section 36 of this township, where about 7 feet of good coal is exposed. The bed probably corresponds to the highest of the three beds in the township to the east (Pl. VII, No. 1B). No coal outcrops were traced, but it is probable that the greater portion of the township is underlain by workable coal.

T. 1 S., R. 46 E.—The high divide between Beaver Creek and Liscom Creek runs across this township from northwest to southeast. Several coal beds are exposed on the higher slopes of this divide, but they underlie comparatively small areas. The important coals for the classification of the township are two in number. North of the Kelsey ranch on Beaver Creek, in sec. 6, T. 1 S., R. 46 E., over 7 feet of coal is exposed in a bank opened by Mr. Kelsey (Pl. VII, No. 2A). The coal is of rather inferior quality, containing specks of clay and small particles of pyrite. Its outcrop is indicated on the map. Sixty feet above this coal is a slag which may be traced southeastward up Beaver Creek to an exposure of coal in the NE. ¼ sec. 27 (Pl. VII, No. 2B). This bed is 11 feet 4 inches in thickness and apparently of good quality. This coal is by barometer 335 feet above Tongue River at the mouth of Beaver Creek. It is probably the same bed as that which is burning about 3 miles north of the Kelsey ranch across the divide, where along a coulée about 20 feet of coal is exposed, but the bed is separated into two benches by 2 feet of brown shale. It is possible that the coal which is here on fire corresponds to one of the two beds which have been described as burning 6 miles northeast of Ashland.

Two other coals occur, one 50, the other 75 feet below the Kelsey bed (Pl. VII, No. 2). The lower is 3 feet 4 inches in thickness in the SW. ¼ sec. 7. No lower coal beds of value were observed above the somber-colored beds in passing down Beaver Creek to Tongue River.

Liscom Creek within the limits of the township has not cut down to the horizon of the Kelsey coal, so that the whole township, except that portion along Beaver Creek indicated on the map, is probably underlain by workable coal.

T. 2 S., R. 48 E.—Several coal beds outcrop along the slopes of the divide which occupies the western portion of this township, but the principal coal of the area is the heavy bed indicated on the map. In the NW. ¼ sec. 28 this bed outcrops at several points along a coulée. A pit opened for mining exposes 7½ feet of clean coal without reaching the bottom of the bed (Pl. VII, No. 3A). In the SE. ¼ sec. 16 the same coal is exposed, but no other exposures of this bed were found within the township, the outcrop being traced by the heavy slag or clinker formed by the burning of the coal. The valley of Pumpkin Creek may be underlain by the bed of coal outcropping in section 18 of the township to the north. This bed is by barometer about 100 feet below the coal here mapped. There is no assurance of its presence in this township, however.

T. 2 S., R. 47 E.—The Otter Creek-Pumpkin Creek divide, which reaches an elevation of nearly 4,000 feet above sea level, runs across the southwestern portion of this township. This divide contains several coal beds which are in general burned along the outcrop, but which probably contain much workable coal. Time was not taken to map these upper beds, as it was considered that the classification of the land would depend on the lower beds in the township. Of these there are two outcropping in the valley of Little Pumpkin Creek, in the northeastern portion of the township. A good exposure of the upper bed occurs in the SE. ¼ sec. 5. The bed is over 7 feet in thickness and the coal is said to be of excellent quality, burning with but little ash (Pl. VII, No. 4C).

A rather poor exposure of the lower coal occurs in the SW. ¼ sec. 35 of the township north of this. About 6 feet of coal were measured here (Pl. VII, No. 4B). Across the divide to the northeast coal which is considered to be this same bed has been mined to a small extent in an open bank. Here the coal is 7 feet in thickness. The outcrops of these two beds were traced in the mapping by means of the slag formed by the burning of the coal along the outcrop.

About 1 mile northeast of the exposure last described a bed 60 feet lower in the section has been worked for local use, and contains 14 feet of good coal. (See T. 1 S., R. 48 E.)

T. 2 S., R. 46 E.—This township occupies an area of considerable elevation between Beaver Creek and East Fork. No coal outcrops were traced here, but the whole area is believed to be underlain by workable coals which outcrop at lower levels in adjoining townships.

In the SW. ¼ sec. 32 about 7½ feet of good coal is exposed in the bed of a coulée and is mined for local use. This coal is by barometer about 400 feet above Ashland.

T. 2 S., R. 45 E.—About 6 miles northeast of Ashland, in sec. 7, T. 2 S., R. 45 E., is a considerable area in which two beds of coal are at present on fire. The beds are about 60 feet apart, the lower being 265 feet above Ashland. Neither of these beds is exposed, but to judge by the amount of settling of the surface over the burned area they are of considerable thickness.

T. 3 S., R. 45 E.—Near the Pete Daly ranch, at the mouth of the East Fork of Otter Creek, 4 miles southeast of Ashland, 38 inches of coal is exposed in the creek bed. The base of the coal is covered. It is probable that this is the same bed as that exposed on Tongue River near Ashland.

T. 3 S., R. 44 E.—In sec. 10, T. 3 S., R. 44 E., 1 mile west of Ashland, a coal bed 5 feet 7 inches in thickness outcrops just above the level of Tongue River. The coal is of good quality and has been mined for local use. Six miles down Tongue River from this point, at the mouth of Culberts Coulee, a careful examination of the river bluff failed to show any coal over 2 feet in thickness at about this horizon. Whether this bed is thinning toward the north or whether it is simply obscured by the slumping of the soft shales is uncertain.

If the writer's correlations prove to be correct, five workable coal beds occur within the first 400 feet of strata above Ashland. Two higher coals were measured, one 10 feet in thickness 700 feet above Ashland, the other 11 feet in thickness 650 feet above Ashland. These are found only on the high divides and extend over comparatively little country. Several heavy slags also were noted, the coals of which were not found. No mine openings were found on the two highest beds. This is not because they are inferior in quality to the lower beds, but because, occurring only in the higher hills, they are more difficult of access.

THE POWDER RIVER COAL FIELD, WYOMING, ADJACENT TO THE BURLINGTON RAILROAD.

By R. W. STONE and C. T. LUPTON.

INTRODUCTION.

The present report is a preliminary statement prepared at the close of the field season, to give advance information concerning the coal resources of a portion of the Powder River coal field, in northeastern Wyoming, adjacent to the Chicago, Burlington and Quincy Railroad.

The Powder River coal field is a small part of a large area of coal-bearing rocks, known as the Northern Great Plains Province. Beginning at Casper and Douglas, on North Platte River, in Wyoming, this province extends northward between the Black Hills and Bighorn Mountains, occupies the eastern part of Montana and all the western half of North Dakota, and reaches into Canada. The examination of that part of the province which lies in Wyoming alone is a matter of several years' work. In 1907 a Geological Survey party under J. A. Taff surveyed the Sheridan district, and another under E. W. Shaw examined the south end of the province between Douglas and Casper. In 1908 H. S. Gale surveyed a field in the vicinity of Buffalo and Trabing and the writers examined a block of townships along the Burlington Railroad, adjoining the areas covered by Taff and Gale, and extending to the eastern limit of the coal field.

The area described in this paper lies between Clearmont and Rozet. It has an east-west length of 60 miles and an average width of over 20 miles. It includes practically 1,400 square miles, or 39 townships.

The primary purpose of the investigation was to determine the amount of land underlain by workable coal beds and to locate the eastern limit of the coal field. The writers were assisted by F. D. Morrison and C. M. Holmes, jr., who, in addition to their duties as camp hands, rendered considerable service in making compass traverses, collecting fossils and coal samples, and assisting in the topographic work.

The region under discussion was surveyed by the General Land Office in 1883, but practically no section corners bearing evidence of having been set during the original survey could be found. Under these conditions it was useless to follow section lines, and on account of the rough character of the country it was impossible to travel in straight courses and to measure distances by pacing; therefore a 2½-mile base line was measured on the Powder River flat, 6 miles north of Arvada, a system of triangulation on prominent buttes was developed, and a topographic map of a part of the area, on a scale of a mile to the inch, was made by the use of 15-inch plane tables and open-sight alidades. A little less than half of the total area, or between 600 and 700 square miles, was mapped in this way. The meandering course of Powder River above Arvada was mapped by a foot and compass traverse. The outcrops of the principal coal beds were sketched with the topography. A profile of the Burlington Railroad, Geological Survey bench marks along Clear Creek, and aneroid-barometer readings were used for vertical control.

LOCATION AND COMMERCIAL RELATION.

The geographic position and outline of the district are shown on the index map (Pl. VIII), which also shows its more general geographic relations.

The Burlington Railroad is the only line at present crossing the Powder River coal field in northeastern Wyoming. The construction of a railroad down Powder River to the Yellowstone is feasible, and such a road would make a much larger part of the coal field readily accessible. Thirty-nine townships lying along or close to the railroad, and therefore more readily accessible and open to development whenever a demand arises for this coal, were selected for examination by the writers in 1908 and constitute the area described in this paper.

Settlers are few in this country because of the scarcity of water. The principal occupation is cattle and sheep raising. Gillette, Arvada, and Clearmont, the only villages, have a total population of about 500. Gillette is the largest, with about 300 people, and Arvada is the smallest, its population numbering between 50 and 75. Aside from these villages on the railroad, settlement is confined to the valleys of the main streams, the most desirable land lying along Crazy Woman and Clear creeks and Powder River. These streams are perennial, but all the others in the area are intermittent, flowing only about three months in the year. Along the intermittent streams windmills are used commonly for pumping water from deep wells for both stock and domestic use. The Burlington Railroad pumps water from deep wells at Felix and Gillette to supply its locomotives and section men. It is a common practice among the ranchers to store ice for drinking water during the summer, as the ice water contains much less alkali and sediment than the normal stream flow.

Timber is scarce in this area, being limited almost entirely to cottonwood along the main stream courses and to scattering pine and cedar in the hills.

TOPOGRAPHY.

The Powder River coal field lies in the Great Plains province, between the Bighorn Mountains and the Black Hills. Much of it is so deeply dissected that the original plains character is suggested and represented now only by the crests of the main ridges, which are all at about the same elevation. The topography of the region between Clearmont and Oriva is mainly of the badland type, especially close to the main streams, but there are small areas of more gentle relief in Tps. 54 and 55 N., R. 76 W. Vegetation is scanty and when rain falls numerous rivulets form, each carving a channel in the soft clay or sand. The result is an intricately dissected and irregular surface over which it is difficult to travel. East of Oriva the topography is in large part of moderate relief, although there are some areas of extreme dissection.

In the badland areas bare slopes are everywhere conspicuous. From elevated points in these areas one sees innumerable steep-sided ridges, buttes, domes, precipitous bluffs, and, in places of recent sharp dissection, pinnacles capping the ridges and old valley bottoms dissected by vertical-walled coulées.

In some parts of the area the coal beds are burned along the outcrop, the overlying clay being baked to a resistant mass that forms ledges in the steep sides and caps small mesas and numerous detached buttes.

The areas of more gentle topography are grass-covered and prairie-like and exposures of bed rock are much less common in them than in the badland areas.

The altitude of the region ranges from about 3,600 feet above sea level on Powder River at the mouth of Clear Creek to about 4,900 feet on the hilltops in the divide near Sparta, west of Gillette.

GEOLOGY.

The rocks of this area consist of a series of clay, shale, sandstone, and coal beds, alternately stratified, apparently conformable throughout, and belonging to the Fort Union formation. In the Sheridan field the formation was divided by Taff on lithologic grounds into a lower member, consisting of 2,500 to 2,800 feet of dull-drab, bluish, and brown shale, and an upper member, consisting of 2,200 feet of bluish and brownish shales and sandstones interstratified with many coal beds. He also subdivided the upper member into the Tongue

River, Intermediate, and Ulm coal groups, and this grouping will be followed in the present paper for convenience of description.

The lower member is exposed in this area only east of the line of burned rock extending north and south through Minturn and marking the eastern limit of the coal field. These beds are essentially all clay or shale and are prevailingly light colored. They contain bands of dull red and brown beds which, where weathered and washed down, may mask the lighter beds and give a dull color to the whole. These beds also contain numerous nodular concretions ranging up to several feet in length, which, because of their iron content, on weathering become yellow or rusty to dark brown. In clean-washed slopes these nodules make conspicuous dark spots in the light-colored clay; on deeply weathered slopes where the nodules are abundant and disintegrated to granular fragments they give a dark tone to the surface.

The thickness of the lower member in this area is not readily measurable, but may approximate 1,000 feet. The member contains two or three coal beds less than a foot thick.

Above these beds is a series of clay, sandstone, and coal beds called by Taff the Tongue River coal group, from their occurrence on that stream. At the type locality the group is about 800 feet thick and contains seven workable coal beds. In the Powder River field the group outcrops between Minturn and Gillette in a north-south belt, but it is so tilted and burned that its thickness can not be measured. A portion of the coal group is exposed also on Powder River, 6 to 10 miles below Arvada. Between the lowest rocks on Powder River at the state line and the highest beds of the group is an interval of 575 feet, containing at least five coal beds. As the base of the group is under cover at the state line the total thickness was not determined.

On Tongue River the sequence of coal beds is as follows:

Coal beds of the Tongue River coal group.

	Feet.
Roland coal bed (variable)	13
Interval	125
Smith coal bed (variable)	5
Interval	210
Dietz No. 1 bed	8
Interval	100
Dietz No. 2 bed	8
Interval	100
Dietz No. 3 bed (variable)	12
Blue shale, etc.	120
Monarch coal bed	18-22
Interval	58
Carney coal bed	12-17

The clay beds of the Tongue River coal group vary from light fine-textured material to dark coaly shale on the one hand and to sandy shale on the other. The sand is in general only slightly consolidated and for the most part is light colored, white or slightly iron stained, giving to the coal group the name "yellow beds." In places the sand is cemented by iron or lime and forms ledges. The beds of sand vary in thickness from mere streaks to great masses measuring from 40 to 100 feet. Cross-bedding is common, but grits are rarely found. Owing to the horizontal position of the beds and the numerous large bare exposures in the badlands along the river, the thick beds of white sand can be traced with the eye for miles.

The Intermediate coal group, which is described by Taff as having a thickness of 1,150 feet in the Sheridan district and extending from the Roland coal bed up to the Lower Ulm coal bed, in this district seems to be about 900 feet thick. Sand and clay, with less abundant beds of shale, compose the group. It is more sandy in the lower than in the upper half. Bands of brown carbonaceous shale are scattered throughout, being the more numerous perhaps in the upper part. A conspicuous feature of the lower part of the group is a fossil shell bed which occurs about 175 feet above the Roland coal bed and which is so continuous and so readily seen as to make an excellent horizon marker. Above this shell bed, in places resting on it and elsewhere separated from it by 30 to 40 feet of sand, is a workable bed of coal. This is the lower coal of the two workable beds found in the group in this area. It is called the Arvada coal bed, from its occurrence at that place. The other is the Felix coal bed, which occurs about 350 feet higher in the section and has been mined at Felix, Echeta, and Croton, on Wildhorse Creek.

The Ulm coal group comprises the highest beds in the Powder River field. Its base is marked by a bed of coal which is widely distributed and which is found about 350 feet above the Felix coal bed. In the Sheridan district erosion has largely removed this bed and in the Powder River field it is found only in the highest hills, where it has been extensively burned along its outcrop. That part of the group which has not been eroded is nearly all white sand and is about 150 feet thick. Bands of carbonaceous shale, which may represent the horizon of the Upper Ulm coal bed, cap the geologic section in this district.

Baked shale and clay, made bright red by the burning of an underlying coal bed, occur at the various coal horizons in nearly all parts of the field.

Collections of fossil plants and shells made in this and adjoining districts have been examined by F. H. Knowlton and T. W. Stanton, who agree that the beds from which the fossils were obtained are of Fort Union age. This determination makes the age of the coal-bearing rocks basal Tertiary, or, more definitely, lower Eocene.

The geologic structure of the region is extremely simple. As has been described and figured by Darton,[a] the country between the Bighorn Mountains and the Black Hills is a shallow structural trough having a steep western rim. In this rim the rocks dip sharply away from the Bighorn Mountains, but in the vicinity of Clearmont they are practically horizontal. The beds lie flat through the Powder River and Wildhorse Creek country, but begin to dip slightly to the west near Oriva. From this point eastward to Minturn the dip increases to a maximum of about 2° and flattens again near Rozet. The westward dip near Gillette is sufficient to bring the Tongue River coal group to the surface within a short distance. This slight monocline, near Gillette, strikes nearly north and south and determines the eastern limit of the coal field. Besides the main structural features there are minor warpings of the strata, but the vertical control of the map work was not of sufficient accuracy nor the plan of the work detailed enough to determine the amount or extent of the irregularities. One of the most conspicuous of the minor features is a low wave in the structure at the mouth of Twentymile Creek, just east of Echeta.

THE COAL.

DESCRIPTION OF COAL BEDS.

GENERAL OUTLINE.

In a brief preliminary report it is not possible to offer all the details of the geologic section or to give a large number of close measurements of coal beds. Neither is it possible to state with definiteness the correlation of certain features throughout the area described or their relation to adjoining areas. For this reason the statements which follow are in part somewhat generalized. They are intended to give the conclusions concerning the area and a fair amount of the data on which the conclusions are based. The accompanying map (Pl. VIII) showing the distribution of the coal beds was reduced from the original map, contour lines being omitted. In a subsequent report, prepared after the material in hand has been more thoroughly studied, it will be possible to give more details of the numerous coal beds and to discuss scientific questions.

The principal coal beds in this area are five or more in number. They are generally free from partings of clay or shale and are of considerable known extent. The field work of 1908 was done under the coal-land classification schedule, which considered subbituminous coal less than 4 feet thick as nonworkable. Although it is possible that beds of coal less than 4 feet thick may be mined in this field in the distant future, the distribution of beds of much greater thickness is so widespread that those less than 4 feet thick were not mapped.

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[a] Prof. Paper U. S. Geol. Survey No. 32, 1905.

The beds of coal which will be described are as follows:

Principal coal beds in Powder River field.

	Feet.
Lower Ulm or Healy coal bed	10- 15
Interval	300
Felix coal bed	6- 30
Interval	375-400
Arvada coal bed	5- 10
Interval	125-225
Roland coal bed	3- 7
Interval	80
Smith coal bed	4- 10

Besides the coal beds named above, there are numerous other beds of coal distributed throughout the geologic section above described. They range from a few inches to several feet in thickness, but the thicker beds are of small geographic extent.

The description of the coal beds will begin with the lowest in the geologic column exposed in this area and give briefly the character of the bed, its extent, and the points where it is well exposed.

SMITH COAL BED.

A coal bed which outcrops at or just above water level along the lower course of Clear Creek is believed to be the same as the Smith coal bed of the Sheridan field, described by Taff as occurring about 560 feet above the well-known Monarch coal bed. The best exposures of this bed are in the cut banks of Clear Creek in the northern part of T. 55 N., R. 78 W., where it has an almost constant thickness of 10 feet of clean coal. An analysis of a sample (No. 6460) cut from a fresh face in the creek bank (No. 2)[a] in the NW. ¼ NW. ¼ sec. 12, T. 55 N., R. 78 W., is given in the table on page 133. A coal bed at about the same horizon occurring about 75 feet above Powder River at the northwest corner of sec. 2, T. 55 N., R. 77 W., near the Lynn ranch has a thickness of 4 feet 3 inches. The outcrop of this bed along Powder River is not shown on the map.

Because of the practically horizontal position of the rocks and the fact that this coal is near water level in the lowest part of the district, it is readily seen that if this bed is continuous it must underlie the entire coal area of this field.

ROLAND COAL BED.

A coal bed at the top of the Tongue River coal group, described by Taff as having a thickness of 13 feet in the Sheridan district but diminishing to 2 feet toward the south, was called by him the Roland coal. A coal bed in the Powder River field having about the same geologic position, 150 feet below a conspicuous bed of fossil shells, will be described here as the same coal bed. It is conspicuously exposed in the bank of Powder River at water level by the schoolhouse near David Campbell's (No. 5), in sec. 22, T. 55 N., R. 77 W., about 6 miles north of Arvada. Here it has a thickness of 7 feet, which it probably maintains for some distance, as it is 7 feet thick near the Lynn ranch on Powder River at the north edge of the same township. On Jim Creek just south of the township line (No. 7) in T. 55 N., R. 76 W., the Roland coal bed, lying beneath 20 to 30 feet of massive buff sandstone, is in two benches, the upper one 7 feet 8 inches thick and the lower one 2 feet 3 inches thick, separated by 3 feet of gray clay and shale.

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[a] Numbers in parentheses refer to locations on the map (Pl. VIII).

On Clear Creek in sec. 31, T. 56 N., R. 77 W., in the hills north of the Culture ranch, what is believed to be the same bed has a thickness of 3 feet 8 inches, including a 6-inch parting of brown shale. The outcrop of this bed on Clear Creek is not shown on the map. As this coal bed passes beneath the river at Campbell's, the outcrop in the area here described is of small extent. The bed certainly is worthy of some consideration on Powder River, but whether it is of workable thickness for any great distance where deeply buried is a question which can not be answered until the area has been prospected by the drill.

ARVADA COAL BED.

The name Arvada is given to a coal bed in the lower part of the Intermediate coal group which has been mined on a small scale at Arvada, on Powder River. About 1 mile above Arvada this coal is at water level, and on Wildhorse Creek it disappears at the junction of the middle and south forks. It outcrops for a number of miles on Clear Creek, going below water level at the railroad bridge west of Cadie. This coal bed is readily recognized by the occurrence beneath it of a bed of gray sandstone carrying an abundance of large and small gasteropods and a unio. It varies in thickness up to 12 feet, and is so much harder than the rock above and below that it is exposed as a ledge or breaks up into a talus of solid blocks. Usually the shells can be found in the soil or in the stream beds just below the outcrop. In some places the Arvada coal bed rests directly on the fossil bed, but in others the two are separated by 20 to 40 feet of sandstone.

Half a mile south of Arvada where the coal bed has been mined in the bank of the river (No. 9) it has a thickness of 12 feet 8 inches. This is all clean coal with the exception of mere streaks of mineral charcoal. The upper half is thin bedded and the lower half blocky. At Campbell's schoolhouse, 6 miles north of Arvada (No. 5), the coal bed is [illegible] 7 feet 8 inches thick, and at Lynn's 4 miles farther down the river (No. 6) it measures 5 feet 8 inches. At Lynn's the coal is about 80 feet above the river and at Campbell's from 230 to 250 feet above the river. In a draw 1 mile below Davis ford, on the west side of Clear Creek (No. 1), in sec. 3, T. 55 N., R. 78 W., the Arvada coal bed has been dug by ranchers from the outcrop in the bank of a small tributary. The section of the coal bed at this point is as follows:

Section of Arvada coal bed near Davis ford (No. 1), sec. 3, T. 55 N., R. 78 W.

	Ft.	in.
Coal	9	
Shale, brown carbonaceous	2	
Coal	2	6
	13	6

The coal here is separated from the fossiliferous sandstone below by 3 feet of brown shale.

J. N. Sweat has opened a mine on this coal bed in a ravine 1½ miles north of Kendrick (No. 3), in the NE. ¼ sec. 13, T. 55 N., R. 78 W. Here the bed averages 9 feet in thickness and is free from partings other than a half-inch streak of mineral charcoal.

The record of a well drilled at Gillette by the Burlington Railroad shows at a depth of 350 feet a coal bed reported to be 55 feet thick. The writers believe that this bed is at about the same geologic position as the Arvada coal, but question whether its thickness is so great as stated. It is likely that there is coal of considerable thickness, but it is probable that a part of the bed is brown shale; at least the evidence afforded by sand pumpings from a churn drill is not wholly conclusive.

From the character of the Arvada coal bed on Clear Creek, Powder River, and Wildhorse Creek, it may be concluded with some certainty that this bed underlies a considerable part of the area mapped and that it is of workable thickness.

Samples of the Arvada coal were taken at the Sweat mine (No. 6798) near Kendrick (No. 3), and at the Arvada mine (No. 9). At the latter point two samples were taken, one (No. 6459) representing the whole bed, and the other (No. 6461) representing the lower half or blocky part of the bed. Analyses are given on page 133.

FELIX COAL BED.

At Felix, a station on the Burlington Railroad near the head of Wildhorse Creek, a thick bed of coal is conspicuously exposed both on the main stream and in a draw on the north. Being close to the railroad it attracted attention and a mine was opened here a dozen or more years ago. It will be called in this report the Felix coal bed, as this is probably the first place in the region where the bed was worked.

The position of the Felix coal bed is about 375 to 400 feet above the Arvada coal bed, or near the middle of the Intermediate coal group. East of Powder River it is for the most part 10 feet or more thick, is readily found in natural exposures in many coulées, and where burned is traced without difficulty by the red baked clay. Like the other beds of workable thickness in this area it consists of solid coal practically free from partings.

An exposure of this coal bed in the bank of Wildhorse Creek, one-third mile below Felix (No. 20) has an apparent thickness of 40 to 50 feet. That this is the result of a slip was proved by a drift at the base running through the coal into clay. The bed at this point is actually about 16 feet thick. A small mine was opened here and operated for a short time. On the first tributary of Wildhorse Creek entering from the north below Felix this bed is exposed at two or three points and is between 20 and 25 feet thick. The outcrop is maintained at water level for some distance by a slight westerly dip of the rocks.

The easternmost occurrence of the Felix coal bed in this area is at Gillette. Here the rise of the rocks brings the bed to the surface and carries it above the plains to the east. The coal is mined 1 mile west of town by W. F. Vines. The section at his mine is as follows:

Section of Felix coal bed at the Vines mine, Gillette.

	Ft.	in.
Coal, with clay bands up to 1 foot thick	9	10
Shale and clay	1	6
Coal	1	
Clay, drab	5	
Shale, bituminous		8
Coal, clean and solid	7	6
	25	6

Seven miles due south of Gillette on the west side of the road (No. 27) in sec. 34, T. 49 N., R. 72 W., the Felix coal bed, exposed in natural outcrop and also partly excavated, has a thickness of 22 feet, the upper 7 feet containing thin bands of shale. Where this bed crosses Caballo Creek, 7 miles farther south (No. 28), a thickness of 6 feet 8 inches of coal is exposed in the creek bank. The bottom of the bed is not visible.

B. H. Barker mines the Felix coal bed in a ravine about 2½ miles northwest of Gillette (No. 26), where it has the following section:

Section of Felix coal bed at Barker mine (No. 26).

	Feet.
Coal	13
Clay, carbonaceous	4
Coal	9
	26

The analysis of a sample taken in this mine about 150 feet from the surface is given (No. 6542) in the table on page 133. West of the Barker mine, on the head of Rawhide Creek, the bed is somewhat thicker. An exposure in the draw 2 to 3 miles north of Sparta is as follows (No. 24):

Section of Felix coal bed near Sparta (No. 24).

	Ft.	In.
Coal	14	
Clay, carbonaceous		3
Coal, woody structure, poor	2	
Shale and clay, carbonaceous	5	6
Coal	9	
	30	9

On a branch of Rawhide Creek 3 miles northeast of Oriva (No. 23) the Felix coal bed is in two benches, but shows some variations from the section last given.

Section of Felix coal bed northeast of Oriva (No. 23).

	Ft.	In.
Coal	13	
Shale and clay, carbonaceous	4	3
Coal, woody structure, poor	2	
Shale and clay, carbonaceous		4
Coal	8	
	27	7

In the vicinity of Echeta the thick Felix coal bed is contained in massive white sandstone. Talus from the sandstone above, which is readily traced for miles, commonly conceals the coal. Good exposures at wide intervals show that the coal bed maintains a considerable thickness over a large area in this part of the district. On Twentymile Creek, near the E. W. Haines ranch (No. 17), in sec. 18, T. 52 N., R. 74 W., the bed is well exposed and shows a clean face of 19 feet of coal with only three partings of clay, each less than 1 inch thick.

At Echeta the Felix coal bed has the greatest thickness seen in the district. In a ravine one-fourth mile west of the railroad station (No. 18) the bed is well exposed, one of the side gulches being wholly in the coal. Here the total thickness of the bed, which is free from partings, is fully 30 feet. An entry has been driven 60 feet on the coal. A sample taken at the face of the entry, including about 8 feet of the middle of the bed, gave the results (No. 6448) shown in the table of analyses, page 133.

The Martin mine was opened on the Felix coal bed at Croton (No. 16) in 1902. Its development, however, never extended beyond a single drift without rooms. The bed at this point is 11 feet thick and the quality of coal is shown in analysis No. 6432 on page 133. In the hills north of Croton, reached by a rough road from Whittenmeyer's ranch, this coal bed is exposed in a number of coulées (No. 15) and ranges in thickness from 12 to 14 feet. It is overlain by about 50 feet of white sandstone and underlain by 20 feet of similar material. On the north side of the ridge between the south and middle forks of Wildhorse Creek (No. 14), in sec. 36, T. 54 N., R. 76 W., this bed has a thickness of over 16 feet, but in the hills between the middle and north forks and in T. 55 N., R. 76 W., it is commonly from 4 to 6 feet thick. It is exposed at the road gaps in secs. 22 and 28 (No. 8), T. 55 N., R. 76 W., in the midst of a considerable thickness of brown shale, and in each place is 6 feet thick.

About 4 miles southeast of Arvada, in the hills behind Tinkham Butte (No. 10), the Felix coal bed is 10 feet thick without partings, and farther south, in the hills west of Lorah's ranch, 1 mile below the mouth of Crazy Woman Creek (No. 12), it measures 9 feet 6 inches. Here the massive yellowish-white sandstone commonly occurring above the coal is separated from it by 23 feet of drab clay. Near Pendergraft's ranch, on the west bank of Powder River 2 miles above the mouth of Crazy Woman Creek, the bed is much thinner.

Section of Felix coal bed near Pendergraft's ranch.

	Ft.	in.
Coal	4	10
Shale, carbonaceous		3
Coal		2
	5	3

On the east side of Powder River, however, about 1 mile above the mouth of Fortification Creek, the following section was measured:

Section of coal bed above Fortification Creek.

	Ft.	in.
Coal	2	2
Clay, drab	4	2
Coal	5	5
Shale, carbonaceous	1	2
Coal, part blocky	5	
Clay, drab		3
Coal	1	1
	19	3

A little farther south, about one-fourth mile east of the river, on the east side of sec. 29, T. 52 N., R. 77 W., the same bed shows 9 feet 6 inches of clean coal; and still farther south, on the east bank of the river in sec. 32, the section is as follows:

Section of Felix coal bed in sec. 32, T. 52 N., R. 77 W.

	Ft.	in.
Sandstone, gritty		
Coal	3	
Shale, carbonaceous	1	
Coal	1	
Shale, carbonaceous	2	
Coal	4	3
	11	3

These sections show that the Felix coal bed near the Pendergraft ranch varies considerably in thickness. East of the mouth of Crazy Woman Creek the bed shows 9 feet of coal in clean exposure in the coulées a mile or more back from the river.

West of Powder River, in the valley of Crazy Woman Creek, the Felix coal bed is thinner, and where it passes below water level 5 miles above the mouth of the creek it measures 5 feet.

LOWER ULM COAL BED.

The Lower Ulm coal bed is about 400 feet above the Felix coal and is considered by Taff as the basal member of the subdivision which he calls the Ulm coal group. This coal in the Buffalo district is described by Gale as the Healy coal bed.

High in the hills over the greater portion of the area under discussion there is commonly a band of red baked clay which probably indicates the position of the burned outcrop of the Lower Ulm coal bed. In some portions of the area the abundance of baked rock suggests that practically the entire bed has been consumed, but in other portions the burning is limited to the spurs and unburned coal is found at the heads of the draws. The amount of burned material and outcrops of unburned coal indicate that the bed is of considerable thickness and therefore of some value.

This coal bed is not known to occur north of the railroad on the west side of Powder River, but between the railroad and Crazy Woman Creek its position is readily traced by the baked clay. Outcrops of the unburned coal in this locality are few. The best exposure known to the writers is about 8 miles south of Arvada and 3 miles northwest of the schoolhouse near Stott's ranch on Powder River (No. 11). At this point the section of the coal bed is as follows:

Section of Lower Ulm coal bed in sec. 29, T. 53 N., R. 77 W. (No. 11).

	Ft.	In.
Coal	2	6
Shale, carbonaceous	2	
Coal	11	
Shale, carbonaceous	1	
Coal	1	6
	18	

The coal in the upper and lower benches of this section is somewhat dirty and therefore of little value, but that of the 11-foot bench is hard and clean. An analysis of it (No. 6444, p. 134) shows only 3 per cent of ash and less than 7 per cent of moisture when air dried.

In the hills on the west side of T. 52 N., R. 78 W., there is a coal a little over 5 feet thick. This probably corresponds with what is known as the Healy coal in the townships farther west. In the high butte 4 miles southwest of the mouth of Crazy Woman Creek, about 400 feet above the Felix coal, there are two beds of coal separated by 10 feet of clay. The upper bed is 2 feet and the lower one 4 feet thick. Whether these are at the horizon of the Lower Ulm coal bed is a question. It is possible that a thick bed of brown carbonaceous shale occurring about 75 feet below is at the proper horizon for the coal bed under discussion.

East of Powder River the extent and thickness of the Lower Ulm coal bed are well determined by good exposures. Northwest of Croton, in the top of the ridge between Wildhorse and Deer creeks, this coal bed has a thickness of 12 feet 6 inches, and at the head of Deer Creek (No. 13) it was found at one point 10 feet thick and at another 11 feet 3 inches. West of Felix, in the SE. ¼ sec. 16, T. 51 N., R. 75 W., in the head of the coulée which drains to the east (No. 19) the Lower Ulm coal bed measures 11 feet 10 inches without partings. South of the last-mentioned locality, probably in sec. 32, T. 51 N., R. 75 W., there are good exposures which show at least 10 feet of coal, and on Caballo Creek east of the 4 J ranch, in the southern part of T. 48 N., R. 74 W., it is at least 8 feet thick.

On the heads of Wildhorse and Rawhide creeks, north of Oriva, the Lower Ulm coal bed is burned extensively and probably only a little of it remains. The baked clay that marks the horizon is so resistant that it forms small mesas and round buttes, which give to the topography of this area an appearance somewhat different from that observed elsewhere in the field. Instead of the badlands which abound along Powder River, the surface here is that of a prairie thickly set with small round buttes, each with a capping of red baked clay. The amount of burning suggests that the coal bed in this locality was thick. Evidence on this point is shown at an outcrop on the east face of the hill 1 mile northeast of Sparta (No. 25):

Section of Lower Ulm coal bed near Sparta (No. 25).

	Ft.	In.
Coal	9	
Shale, brown, woody		2
Coal	10	3
Shale, carbonaceous		5
Coal	6	3
Shale, brown, woody		4
Coal		6
	26	11

This outcrop marks practically the eastern limit of the Lower Ulm coal bed, for the monocline extending north and south brings lower rocks to the surface within a short distance. There are a few outliers farther east, but it is probable that in most of these the coal is burned. Antelope Butte, 8 miles south of Gillette, is capped by baked clay marking the horizon of this coal.

OTHER COAL BEDS.

The eastern limit of the Powder River coal field is determined by a broad irregular belt of baked clay and slag which extends north and south from the railroad in Rs. 71 and 72. The coal beds that have been the source of this burning are exposed at only a few places. Near Minturn a coal bed which has been prospected by Andrew Ditto in the NE. ¼ sec. 2, T. 49 N., R. 71 W., measures as follows:

Section of coal bed and associated rocks near Minturn.

	Ft.	In.
Clay, sandy	15	
Shale, brown, woody, with coal streaks	3	
Clay, drab	4	
Clay, sandy, yellow	3	
Shale, brown, woody, thin coal streaks	19	
Coal	2	6
Shale, brown, woody	1	10
Coal		10
Clay, brown and black	1	
Coal, base of bed not reached	8+	
Total coal	11	4+

It is reported that a prospect sunk 18 feet on this lower bench failed to reach the bottom of the coal.

Nine miles north of Gillette, in the NE. ¼ sec. 10, T. 51 N., R. 72 W., at what is known as the Hulbert mine (No. 22), there is a coal bed similar to the one at Minturn.

Section of coal bed at Hulbert mine (No. 22).

	Feet.
Sandstone, yellowish gray, with lenses of clay, brown	20
Coal and brown shale	6
Coal, good, bottom not reached	22+

Neighboring ranchers obtain fuel here and some has been hauled by wagon to Gillette. An analysis (No. 6602) of a sample taken at this mine is given in the table on page 134.

The following section (No. 21) was measured about 7 miles farther north, at the western edge of the burned area in the NE. ¼ sec. 3, T. 52 N., R. 72 W. It represents the coal bed 2 miles north of John Grant's ranch.

Section of coal bed in sec. 3, T. 52 N., R. 72 W. (No. 21).

	Feet.
Sand and sandstone	10±
Clay, drab	15±
Coal and brown shale	4
Coal, good, black	16
Coal, fair, brownish	5
Clay, yellow	1
Clay, drab	6
Total coal	25

This bed is well exposed in a bluff, and Mr. Grant obtains coal here by prying it from the outcrop with a crowbar.

The three outcrops described above are at the western limit of the slag-covered area. In view of this fact and the similarity of the sections, it seems possible that these are all sections of the same coal bed, but they could not be correlated owing to the lack of exposures.

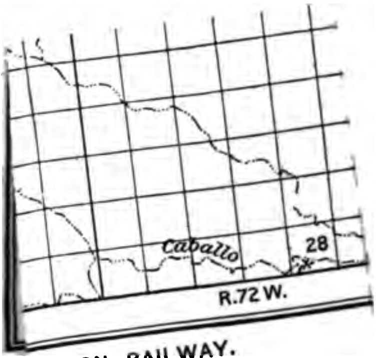
The Chicago, Burlington and Quincy Railroad Company sunk a churn-drill hole to a depth of 865 feet at Gillette in 1897 to procure a supply of water. In 1906 a second hole, within a few feet of the first, was drilled to a depth of 1,560 feet. Generalized sections of these wells as reported are given below:

Sections of water wells at Gillette.

No. 1.	Feet.	No. 2.	Feet.
Sandstone and shale	345	Soil, shale, and sandstone	335
Coal	55	Shale, dark, with coal streaks	65
Shale, white, black, and blue	85	Clay, shale, and sandstone	90
Coal	35	Coal	22
Shale and sandstone	345	Shale, sandstone, and limestone	1,048
	865		1,560

In the first well, at 345 feet below the surface, 55 feet of coal is recorded; in the second well, at the same depth, 65 feet of dark shale with coal streaks is reported. As the wells are only a few feet apart, and such an abrupt change in character in so short a distance is not common, this carbonaceous member is probably the same in both wells. Pumpings were not kept, however, and there is no way of telling whether it is actually a very thick bed of solid coal or a series of alternating beds of dark shale and coal. In both wells, at about 490 feet below the surface, or 85 to 90 feet below the upper coal, there is a second coal bed of considerable thickness. It is recorded in one as 35 feet and in the other as 22 feet thick. The first well was sunk 345 feet and the second well 1,048 feet below the lower coal without finding another coal bed. It seems probable that these two thick coal beds, 90 feet apart, the upper one at a depth of 340 feet below the surface, at Gillette, are the ones that outcrop at Minturn, 6 miles to the east, and have been the source of the burning over the broad, irregular belt mentioned above. At least they belong in the Tongue River coal group.

Besides the coal beds already described there are a number of others, probably of local extent only, which are in places of workable thickness. In the vicinity of Echeta there is a 5-foot coal bed about 150 feet above the Felix coal bed and overlain by white sandstone. What may be the same bed is present east of Tinkham Butte, also underlying a white sandstone but much thicker and with a number of partings, being in reality a mass of drab clay and brown, woody shale, containing beds of coal varying in thickness up to 2 feet 6



NGTON RAILWAY.

inches. Still higher in the section, possibly 50 feet below the Lower Ulm coal, there is a bed exposed at the head of Deer Creek, which has the following section:

Section of coal bed at head of Deer Creek.

	Ft.	in.
Coal and fossil wood	2	
Clay, gray	3	4
Clay, drab	1	8
Coal	3	
Shale, brown, woody	2	
Clay, drab	4	
Coal	4	
	20	

Considering the number and extent of the coal beds, averaging over 10 feet in thickness, already described, it seems unnecessary to give further details of the lesser beds.

Location of mines, prospects, and outcrops in the Powder River coal field, Wyoming, adjacent to the Chicago, Burlington and Quincy Railroad.

No. on Pl. VIII.	Location.	Page.
1	Near Davis ford, sec. 3, T. 55 N., R. 78 W	123
2	Bank of Clear Creek, sec. 12, T. 55 N., R. 78 W	121
3	1½ miles north of Kendrick, sec. 13, T. 55 N., R. 78 W	123
4	Near Lynn's ranch, sec. 3, T. 55 N., R. 77 W	122
5	Campbell's ranch, sec. 22, T. 55 N., R. 77 W	122
6	Near Campbell's ranch, sec. 27, T. 55 N., R. 77 W	122
7	Joe Creek, sec. 6, T. 55 N., R. 76 W	122
8	7 miles northeast of Arvada, sec. 28, T. 55 N., R. 76 W	126
9	Near Arvada, sec. 21, T. 54 N., R. 77 W	122
10	4 miles southeast of Arvada, sec. 31, T. 54 N., R. 76 W	126
11	4 miles northwest of Stott's ranch, sec. 20, T. 53 N., R. 77 W	127
12	Lorah's ranch, sec. 9, T. 52 N., R. 77 W	126
13	Head of Deer Creek, sec. 14, T. 52 N., R. 75 W	128
14	6 miles north of Croton, sec. 36, T. 54 N., R. 75 W	126
15	4 miles north of Croton, sec. 14, T. 53 N., R. 76 W	125
16	Croton, sec. 2, T. 52 N., R. 76 W	125
17	Haines's ranch, sec. 18, T. 52 N., R. 74 W	125
18	Echeta, sec. 28, T. 52 N., R. 75 W	125
19	3 miles west of Felix, sec. 16, T. 51 N., R. 75 W	128
20	Felix, sec. 13, T. 51 N., R. 75 W	124
21	2 miles north of Grant's ranch, sec. 3, T. 52 N., R. 72 W	129
22	Hulbert mine, 9 miles north of Gillette, sec. 10, T. 51 N., R. 72 W	129
23	3 miles northeast of Oriva, sec. 34, T. 51 N., R. 73 W	125
24	3 miles north of Sparta, sec. 2, T. 50 N., R. 73 W	125
25	1 mile northeast of Sparta, sec. 13, T. 50 N., R. 73 W	128
26	Barker mine, 2½ miles west of Gillette, sec. 18, T. 50 N., R. 72 W	124
27	7 miles south of Gillette, sec. 34, T. 49 N., R. 72 W	124
28	Caballo Creek, sec. 35, T. 48 N., R. 72 W	124

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

All the coal in this district is subbituminous, of the variety commonly called black lignite, and varies but little in the different beds and in different parts of the area. The fresh coal is shiny black and the weathered coal is dull black. It reduces to a black powder, but the streak made on unglazed porcelain is dark brown. The fresh coal is tough and emits a dull sound when struck sharply with a hammer. In texture it is either dense or woody. In some of the coal having woody texture the grain of the wood from which it originated is perfectly preserved. This feature of the coal is most common in the eastern part of the field; it occurs at the Arvada mine and at other points as far west as Powder River, but is said to be rare in the coals mined in the vicinity of Sheridan. The specific gravity is about 1.3.

Close examination of the apparently dense and homogeneous coal shows that it is minutely banded. The predominating dull black is brightened by paper-thin discontinuous bands of jet-black coal.

When exposed to a dry atmosphere, subbituminous coal begins to check at once. The checking may be along the bedding and at right angles to it, or in irregularly disposed, hackley lines, resulting in chips very irregular in shape bounded by conchoidal faces. The checking is due to the evaporation of the moisture contained in the coal and is accompanied by a snapping sound. A lump of this coal freshly mined and exposed to the hot sun will be deeply checked in a few hours and will readily fall to pieces.

Subbituminous coal is distinguished from lignite by its color, the former being black and the latter brown, and from bituminous coal by the manner in which it weathers. Bituminous coal breaks along straight cleavage plains into prisms and disintegrates very slowly on exposure to the weather.

Subbituminous coal burns with a short yellowish-red flame and for a short time after ignition emits a white smoke that has a bituminous odor. After the early combustion of the volatile matter the coal continues to burn with scarcely perceptible smoke. It leaves a fine white ash.

Small globules of resin are found in some of the coal and commonly there is less than 2 per cent of sulphur. Thin bands of mineral charcoal are also present.

CHEMICAL PROPERTIES.

Nine samples of coal were collected in this district for chemical analysis. They were taken from freshly exposed faces of the beds in prospects and small mines in different parts of the field and should fairly represent the quality of the coal, so far as it may be represented by samples from a field where absolutely unweathered coal is unobtainable for lack of deep mines. In collecting these samples the surface of the coal bed was cleaned to get rid of any dirt, and all weathered or checked coal was carefully removed, so that the analysis might represent as nearly fresh coal as possible. A groove was then cut in this clean surface from the top to the bottom of the bed. The coal thus obtained was caught on a rubber blanket or piece of canvas to keep out dirt and moisture from the floor, was crushed to ½-inch size, thoroughly mixed, and quartered, the opposite quarters discarded, and the remainder remixed. This process was continued until the sample was reduced to 1 quart, which was carefully sealed in a galvanized-iron can and sent to the chemical laboratory.

Analyses of coal samples from the Powder River coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6460	NW. ¼ NW. ¼	12	55	78	10′	10′	24.0	As received	28.8	32.5	34.0	4.7	0.46					4,368	7,862
								Air dried	6.3	42.7	44.8	6.2	.60					5,747	10,345
								Dry coal		45.6	47.8	6.6	.64					6,132	11,038
								Pure coal[a]		48.8	51.2		.69					6,566	11,819
6798	NE. ¼	13	55	78	9′	9′	8.7	As received	18.3	34.6	40.7	6.37	1.15	5.66	53.93	1.05	31.84	5,115	9,207
								Air dried	10.5	37.9	44.6	6.98	1.26	5.14	59.07	1.15	26.40	5,602	10,084
								Dry coal		42.4	49.8	7.80	1.40	4.44	66.01	1.29	19.06	6,261	11,270
								Pure coal		46.0	54.0		1.52	4.82	71.59	1.40	20.67	6,791	12,224
6459	NE. ¼ NW. ¼	21	54	77	10′ 8″	10′ 8″	24.3	As received	29.3	28.6	36.4	5.67	1.21	6.27	45.09	.89	40.87	4,324	7,783
								Air dried	6.6	37.8	48.1	7.49	1.60	4.72	59.56	1.17	25.46	5,712	10,282
								Dry coal		40.5	51.5	8.02	1.71	4.26	63.80	1.26	20.95	6,118	11,012
								Pure coal		44.0	56.0		1.86	4.63	69.36	1.37	22.78	6,651	11,972
6461	NE. ¼ NW. ¼	21	54	77	10′ 8″	Lower half	24.0	As received	29.4	27.0	37.9	5.7	1.92					4,286	7,715
								Air dried	7.1	35.5	49.9	7.5	2.52					5,639	10,150
								Dry coal		38.2	53.7	8.1	2.71					6,070	10,926
								Pure coal		41.6	58.4		2.88					6,605	11,889
6432	NE. ¼	2	52	76	11′	6′ at bottom	19.3	As received	25.8	32.9	35.7	5.6	.39					4,703	8,465
								Air dried	8.1	40.7	44.3	6.9	.48					5,828	10,490
								Dry coal		44.3	48.2	7.5	.53					6,340	11,412
								Pure coal		47.9	52.1		.57					6,715	12,087
6448	NW. ¼ NE. ¼	28	52	75	30′	8′ in middle	18.7	As received	23.5	32.4	37.1	7.0	.60						
								Air dried	5.9	39.9	45.6	8.6	.74						
								Dry coal		42.4	48.5	9.1	.78						
								Pure coal		46.6	53.4		.86						
6542	SW. ¼	18	50	72	26′	7′ lower half of top bench.	25.4	As received	33.5	29.1	28.9	8.5	3.26						
								Air dried	10.9	39.0	38.7	11.4	4.37						
								Dry coal		43.8	43.5	12.7	4.90						
								Pure coal		50.2	49.8		5.62						

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term, it is used in this report as noted above.

Analyses of coal samples from the Powder River coal field, Wyoming—Continued.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6444	NW. ¼	29	53	77	18′	11′ bench in middle.	25.3	As received	30.2	33.2	34.4	2.2	0.83						
								Air dried	6.5	44.4	46.1	3.0	1.11						
								Dry coal		47.5	49.3	3.2	1.19						
								Pure coal		49.1	50.9		1.23						
6602	NE. ¼	10	51	72	22′ +	22′	19.6	As received	28.1	33.2	33.1	5.6	.58						
								Air dried	10.6	41.2	41.2	7.0	.72						
								Dry coal		46.1	46.1	7.8	.81						
								Pure coal		50.0	50.0		.88						

6460. Taken from a fresh outcrop in the bank of Clear Creek at water level and above. Face of bed dressed and individual pieces shaved to remove checked surface. This coal necessarily is somewhat weathered. Sampled by R. W. Stone and F. D. Morrison.

6798. Taken from fresh working face in drift of Sweat & Smith, 1½ miles north of Kendrick, 40 feet from surface. This coal was only slightly weathered. Sampled by R. W. Stone and C. T. Lupton.

6459. Represents whole thickness of Arvada coal bed in mine one-half mile south of Arvada. Coal not absolutely fresh, for mine had not been worked in several months. Sampled by R. W. Stone and C. T. Lupton.

6461. Represents lower half of bed or blocky coal in mine one-half mile south of Arvada. Coal not absolutely fresh, for mine had not been worked for several months. Sampled by R. W. Stone and C. T. Lupton.

6432. Taken from face of mine at Croton, 120 feet from surface. Old working face; coal probably slightly weathered. Sampled by C. T. Lupton and C. M. Holmes, jr.

6448. Taken from face of drift 50 feet from surface in gulch one-fourth mile south of Echeta. Represents middle 8 feet of 30-foot bed of Felix coal. Coal probably slightly weathered. Sampled by F. D. Morrison and C. M. Holmes, jr.

6542. Taken from working face of drift 150 feet from the surface at Barker mine, west of Gillette. Coal as nearly fresh as possible. Represents lower 7 feet of upper bench of Felix coal. Sampled by F. D. Morrison and C. M. Holmes, jr.

6444. Taken from outcrop in sec. 29, T. 53 N., R. 77 W., by dressing it to get fresh coal and shaving individual pieces to remove checked surface. Coal probably slightly weathered. Sampled by R. W. Stone and C. T. Lupton.

6602. Taken from fresh face of open-cut coal bank. All checked coal carefully removed but sample was probably slightly weathered. Sampled by C. T. Lupton.

The air-dried samples show an average of 8.05 per cent moisture, 7.22 per cent ash, and 1.60 per cent sulphur. The heating value of these coals is shown by the calorific determinations to be practically the same as that of the coals in the Sheridan field.[a]

UTILIZATION.

The coal resources of this field are practically undeveloped. Scanty population in the area and the production of coal on a large scale in the Sheridan field have retarded development here. There are several openings and prospects from which ranchers and others obtain coal for winter use, but no active mining is carried on. The more important of these openings are described below.

A small mine was opened at Kendrick in 1908, and a few cars were loaded with coal from the Arvada bed. A company is now contemplating the sinking of a shaft near Kendrick. The plan is to sink deep enough to reach three or four coal beds and work them all from the same shaft. Development is being pushed by J. N. Sweat and J. W. Smith.

A small mine in the bank of Powder River, about half a mile south of Arvada, is the source of fuel supply for some of the people living near. This mine was opened in the winter of 1905 and several cars of coal were shipped. The coal was hauled to the railroad in wagons. Active mining continued only about five months, but the bank is kept open for the small supply which is obtained here each winter.

On the west side of Powder River, about 6 miles above Arvada, in the NW. ¼ sec. 22, T. 53 N., R. 77 W., there is a prospect in the Felix bed, from which near-by ranchers get an occasional load of coal. There are other small prospects in this bed at other points on Powder River and Crazy Woman Creek, but they are little more than cleaned outcrops where a rancher or two has taken a few loads of coal.

Near the station at Croton an entry has been driven 120 feet on the Felix coal bed. Four or five carloads were shipped to Gillette in 1902, but since then no coal has been mined here, except by one or two ranchers living in the neighborhood.

At Echeta, where the Felix coal bed has a thickness of 30 feet, a company is now preparing to strip the coal. As the cover is thin it is planned to strip and quarry as long as the overburden is not too great. The relation of the coal bed to the railroad is such that it will be possible to build a level track from the bottom of the strip pit to the tipple at the railroad, one-fourth mile away. The manager of this company, P. J. Barr, was grading the track in the fall of 1908.

A small mine was opened in the creek bottom at Felix several years ago, and it is reported that coal was shipped by rail. The industry was short lived, however, and the only output now is an occasional load taken from prospects in the first draw north of Felix. The Felix coal bed is mined in a small way near Gillette by W. F. Vines and B. H. Barker. It sells in the village for $2.75 to $3 a ton.

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[a] Bull. U. S. Geol. Survey No. 341, 1909, pp. 135-136.

A workable coal bed comes to the surface at Minturn. A prospect pit in the NW. ¼ sec. 2, T. 49 N., R. 71 W., about 1 mile south of the railroad, is said to have gone down 18 feet in coal and not reached the bottom of the bed. A few loads are dug here each winter by neighboring ranchers.

Another source of fuel supply of local reputation is the Hulbert mine, situated about 9 miles north of Gillette, in the NE. ¼ sec. 10, T. 51 N., R. 72 W. This is a bed 22 feet thick. An opening 15 feet wide extends probably 15 feet back into the hill. Eight feet of coal is left in the roof and from 6 to 7 feet of coal is mined. In spite of the distance some of this coal is hauled by wagon to Gillette.

CONCLUSION.

The production of coal in this field at present is limited practically to the small amounts taken by ranchers for their own use. The near future, however, is likely to see active mining of coal at various places along the railroad.

In 1900 the Chicago, Burlington and Quincy Railroad Company began a series of tests of the Sheridan coals in its locomotives and found that with specially constructed grates of large area and modified fire boxes and stacks the coal could be used successfully. Now all locomotives on the Wyoming division of this road are fired with Sheridan coal. As the Powder River coal field is the eastern continuation of the Sheridan field, and as the physical and chemical properties of the coal are practically the same, it is expected that the Powder River coal will prove equally efficient.

Experiments made by the United States Geological Survey show that subbituminous coal (such as that in the Powder River field) develops an efficiency 2.7 times greater with the gas producer and gas engine than when used in the common steam engine. In fact, the Powder River coals, when used in a gas producer and gas engine, will in all probability produce as much power per ton as the best West Virginia bituminous coals when used with a steam engine. With the further development of the producer and gas engine the mining of these low-grade coals should greatly increase.

As the demand for coal increases, capital will be invested in the development of the large beds described in this report. With a railroad already built through the area, and the Powder River valley north of Arvada offering an abundance of coal and an easy route for a new railroad, it may be expected that in a comparatively short time this portion of the great undeveloped region will be making a large addition to the annual coal production of Wyoming.

THE BUFFALO COAL FIELD, WYOMING.

By Hoyt S. Gale and Carroll H. Wegemann.

INTRODUCTION.

The Buffalo coal field of Wyoming is part of a broad area of coal-bearing strata in Wyoming, Montana, and the Dakotas, commonly known as the Northern Great Plains province. Certain fields or even local districts of this province have become more or less well known as coal-producing centers, but little authentic description of this great area has been available prior to the investigations that have been carried on by the United States Geological Survey in the last few years.

The examination of the Buffalo coal field in the summer of 1908 was a direct continuation of similar work that had been done in the preceding year by Joseph A. Taff in the Sheridan field, to the north. The Buffalo and Sheridan fields are also continuous with or a part of the extensive and valuable coal fields to the east and south of them. A part of this province contiguous with the Buffalo and Sheridan fields, including an area reaching eastward from the vicinity of Clearmont along the route of the Chicago, Burlington and Quincy Railroad, was examined in 1908 by R. W. Stone and C. T. Lupton, whose work forms the subject of the preceding paper in this volume.

The field party in the Buffalo area included, besides the authors, Doane Gardiner, temporary field assistant, who measured many of the detailed hand-level sections given on Plate IX, Alcott F. Elwell, and W. H. Beekly.

TOPOGRAPHY.

RELIEF.

The topography of the Buffalo field may be described in a very general way as that of more or less typical plains, although in detail it presents a variety of types and features which are in many places sharply contrasted. Considered broadly, it comprises portions of the foothill province of the Bighorn Mountains or front range of northern Wyoming and the extreme outer margin of the Great Plains area that stretches between the Bighorns and the Black

Hills. The area included in the coal field proper belongs both geographically and geologically to the plains province.

In a broad way the plains in this area exhibit two general types of topography. Along the foot of the mountains there is a belt characterized by broadly rolling and smoothly rounded slopes, largely covered with surficial deposits of sand, gravel, and bowlders, the surface of which is usually grass covered. Contrasted with these smooth grassy plains are the "red hills," which occupy a more extensive territory to the east and northeast, and which through the intricate systems of dissection and erosion slopes developed upon them merge into the most rugged badland forms. Each of these types may be again subdivided into two more or less distinct classes, so that the topography of the field as a whole may be described under four fairly comprehensive headings, as follows, the arrangement being the order of their position with respect to the mountains: Foothills and upper terraces; smooth grass-covered plains and lower terraces; red hills; badlands.

Skirting the foothills of the Bighorn Mountains and extending down the valleys of the principal streams that head within the mountains is a series of remarkably well-developed gravel-covered terraces. Some of them form broad alluvial plains for a distance of 5 to 10 miles from the mountains, but beyond these plains they are confined to the larger stream valleys, which they follow for great distances. In some places four or five of these gravel-covered terraces may be observed from one point, rising one above another. The slope of their surfaces away from the mountains is usually pronounced. The gravel cap is composed of rounded stream material which varies in size from small pebbles to fair-sized bowlders and whose constituents represent most of the igneous and sedimentary rocks exposed in the mountains near by, from which they were probably derived.

The mantle of sand and gravel on these surfaces is not heavy, a fair estimate being perhaps 5 to 10 feet on the stream terraces. Nearer the mountains the gravel is thicker, but probably its thickness does not exceed 40 or 50 feet in most places. On the surface the gravel has been concentrated by subaerial erosion into a layer 6 to 10 inches thick, forming a protecting cap to the terrace which tends to check its further degradation. This feature is well represented along Crazy Woman Creek near Trabing, where the gravel terraces form a line of low hills along the stream valley, the country back of them, which is covered by a thinner mantle of gravel, having been reduced to a somewhat lower level. Unmistakable glacial polishing was observed on bowlders included in some of these deposits. One locality in which the glacial pebbles were found is on a broad terrace 1 mile north of Buffalo, in the SW. ¼ sec. 23, T. 51 N., R. 82 W.

Between the terraces and the red hills to the northeast is an area of gentle slopes and broad, open valleys. At certain points remnants of terrace gravel occur within this area, and it seems not unlikely that at one time the greater part of it was covered by this deposit. Three miles southeast of Buffalo an extension of the terrace area forms the divide between Clear Creek and Dry Creek, and, as it were, bridges the gap between the terraces and the red hills.

In sharp contrast with the broad, grassy slopes described in the preceding paragraphs is the region of more rugged topography, made conspicuous by its red-capped summits and slag-covered slopes. As mentioned in the discussion of structure (p. 147), the baked rock formed by the burning of the Ulm group of coal beds ceases along a line which crosses the field from northwest to southeast in the line of the general strike of the beds. (See Pl. X.) The area of burned coal is not over 12 or 15 miles in width from northeast to southwest. It follows in general the trend of the mountains. On the northeast the slag has been removed by erosion and the boundary of the red hills is most irregular.

The topography of the red hills is in places very rugged. The beds of baked sandstone and shale resist the agencies of erosion and so form the cap rock of most of the hills. Below the protecting cap the slope of the softer rocks tends to remain steep. The slag beds are almost horizontal over most of the area, so that hills capped by the same bed are of nearly equal altitude. The topography thus developed is that of flat-topped mesas separated by canyon-like valleys. Where erosion has progressed further the mesas are reduced to cones and the valleys are broadened. The baked rock is of many shades of red, brown, and purple, the colors being due to the oxidation of the iron in the rocks by the heat of the burning coal. The contrast between the yellow sandstone and shale of the slopes and the brilliant red rock of the crests of the hills is most striking and enlivens a landscape in many ways dull and unattractive.

Badlands of the usual type occupy the territory of lower altitude to the northeast of the red hills. Here the coals have not burned to any great extent and the topography is not influenced by heavy beds of baked rock. Flat uplands exist at localities which are determined by the presence of thin beds of limestone that form the more resistant layers and prevent the erosion of underlying beds, but the topography is for the most part one of minute dissection. Sharp-crested ridges alternate with steep, narrow valleys. There is no water except that of a few miry springs that seep from the coal beds and what is left in depressions of the coulée bottoms after torrential rains. The slopes of the hills are covered with patches of sagebrush and scanty buffalo grass or are entirely bare. Travel over such an area is often exceedingly difficult.

DRAINAGE.

The drainage system which carries off the surplus water of the Buffalo field includes two important tributaries of upper Powder River—Crazy Woman and Clear creeks, both formerly referred to as "forks" of Powder River proper. Each of these streams is in turn fed by numerous branches of various sizes. Piney Creek, a fork of Clear Creek, is equal in size to that stream, so that the perennial streams of the field are really three in number.

The water in Crazy Woman Creek is somewhat alkaline, but that of Piney Creek and Clear Creek is remarkably pure, being derived directly from the wooded slopes and snow-capped peaks of the Bighorn Mountains. All the other streams of the area are of intermittent character.

Lake De Smet is a body of water about 3 miles in length by a mile in width, lying in the western part of T. 52 N., R. 82 W. Its long axis is approximately parallel to the strike of the rocks in this region, about N. 45° W. The lake has no outlet. At its north end it receives a small stream known as Shell Creek, which flows across a broad, flat meadow almost as wide as the lake itself. A narrow valley to the north connects this flat with the flood plain of Piney Creek. It is stated by General Carrington[a] that in 1866 Shell Creek flowed through this valley and emptied into Piney Creek, the lake having at that time no inlet. At the southeastern extremity of the lake a broad valley may be followed into that of Boxelder Creek.

The Buffalo region is one of comparatively scant precipitation, and away from the foot of the mountains springs are rather rare. The most common are small seeps along the channels of dry or intermittent stream courses. Many of these probably represent the underflow of the valley, a part of which may be brought to the surface by a barrier of some sort or by a relative shallowing of the detritus zone in which it flows. Such waters occurring in the area of comparatively less consolidated Fort Union (Tertiary) strata are in general rather heavily charged with alkaline salts, as are the soils over which they pass.

Springs of another type are locally somewhat common and many of them afford good water. These usually occur along the outcrops of coal beds and, like the underflow currents, are most common along stream channels or in valley bottoms, the most favorable points for water to reach the surface. The coal beds are the best water-bearing strata of the Fort Union ("De Smet") formation, the others being relatively impervious clays and clayey layers. Their waters are frequently charged with iron and sulphur compounds and sometimes with alkaline salts, but usually not to a very objectionable degree. These springs are so numerous within the coal field that it may fairly be assumed that a spring is a good indication of a coal bed, although the coal itself may be concealed by alluvial wash.

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[a] Carrington, H. B., Absaraka, land of massacre, 1878, p. 142. "The water is deep and intensely alkaline and there is neither inlet nor outlet, as the little creek which is crossed before reaching the lake passes by the west end at a few hundred yards distance and turns westward to the Piney Forks, emptying its stream below their junction."

STRATIGRAPHY.

INTRODUCTION.

So far as the older sedimentary formations are concerned, the general stratigraphy of this field has already been discussed at length in the reports by Darton[a] and others. In the present review of the Mesozoic and later rocks, however, some modification of the stratigraphic classification used in former reports is now required, to conform to more recent geologic and paleontologic information.

The vicinity of Buffalo does not offer very favorable opportunities for the study of the Cretaceous and older rocks in the foothill region of the Bighorn Mountains. The rocks on the east flank of the range are steeply tilted and the structure is complicated by faults that tend to obscure the normal relations of the strata. The chief difficulty is, however, that the extensive outwash deposits of bowlders and gravel along the base of the mountains have largely obscured the underlying rocks and only fragmentary information concerning them can be obtained.

PRE-TERTIARY ROCKS.

Of the several formations into which the Cretaceous rocks of this region are divisible, only the upper one, to which Darton has given the name Piney formation, contains coal in commercial quantities. For that reason the other Cretaceous formations will not be considered in this report.

PINEY FORMATION.

The name Piney was used by Darton[b] to designate "the lowest formation of the thick series of fresh-water sandstones and shales of later Cretaceous age formerly designated 'Laramie' lying in the great basin adjoining the Bighorn uplift." It embraces all the rocks between the Parkman sandstone below and the Kingsbury conglomerate member of the Fort Union above, or, in the absence of the Kingsbury conglomerate, between the Parkman below and the "De Smet" (now referred to Fort Union) above. Whether the rocks thus described are a formational unit as Darton considered them, or should be referred as a whole or in part to the Fort Union, is now an open question. On account of lack of more positive evidence on the subject the name Piney is here retained as originally used.

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[a] Darton, N. H., Geology and underground water resources of the central Great Plains: Prof. Paper U. S. Geol. Survey No. 32, 1905; Geology of the Bighorn Mountains. Prof. Paper U. S. Geol. Survey No. 51, 1906; Cloud Peak-Fort McKinney folio (No. 142), Geol. Atlas U. S., U. S. Geol. Survey, 1906.

[b] Darton, N. H., Geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906, p. 59.

As described by Darton[a] the Piney formation southeast of Buffalo is about 2,000 feet thick.

> The lowest beds are sandstones and shales of light color, and the upper members consist of white, red, and green sands and sandstones alternating with layers of green and yellow clays, dark shales, and iron concretions, the latter composed of sand cemented by iron oxide. This formation is extensively exposed along the north side of Rock Creek southwest of Lake De Smet, also on the west slope of the high ridge south of Johnson Creek, and notably in the slopes a mile southeast of T. A. ranch, where it forms badlands.

About 9 miles southeast of the T. A. ranch and 4 to 5 miles southwest of Trabing, in the western part of T. 47 N., R. 81 W., the upper portion of the Piney formation, together with the overlying Fort Union ("De Smet") formation, is well exposed. Near the top of the formation are several thin beds of coarse sandstone which breaks into sharp angular blocks. Associated with these sandstones are beds of pink shale. The underlying strata are dark-brown and drab shales containing numerous beds of coal, several of which are of economic importance. Here and there shale of a greenish cast may be noted. Coarse, friable sandstone also occurs and there are numerous thin beds of blue limestone which weathers to dark red or brown. Shale grades into sandstone and sandstone into shale, both vertically and horizontally. It is rare to find an individual bed which can be traced for any great distance. The coal beds form one exception to this statement, for, although varying in thickness and quality, many of them extend over considerable areas.

Near Buffalo no coal beds of importance are known in this formation, but south of Crazy Woman Creek coal is mined at various points in T. 44 N., R. 81 W.; T. 43 N., R. 79 W.; and T. 42 N., R. 77 W., in beds which probably correspond to those near Buffalo. Although this upper portion of the Piney formation resembles in many ways the somber-colored shale which underlies the typical Fort Union in the vicinity of Miles City, Mont., there is some doubt as to its exact correlation.

In T. 43 N., R. 79 W. (see Pl. XI) the rocks underlying the typical Fort Union come to the surface along the flank of a broad dome drained by Salt Creek. The northeastern portion of the township is covered by the fine-grained buff sandstones and shales of the lower portion of the Fort Union, which is here barren of coal beds. This sandy phase passes into darker shale below without any sharp line of contact between the two formations. The shale is approximately 600 feet thick. It is of various shades of gray, some layers being nearly black and others almost white. In its upper part are several pinkish beds. About 300 feet below the top are two beds of coal to be described later. Numerous thin beds of blue limestone which weather to a dark-red color occur, especially near the base of the shale and in the underlying sandstone. This sandstone, about 500 feet in thickness, forms a very prominent pine-covered ridge. It is for the most part bluish white in color and fine grained.

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[a] Loc. cit.

Below the sandstone is a mass of shale with thin sandstone and limestone beds and below this a white sandstone which forms a less prominent ridge than the one just described. In the shale valley between these two ridges some plant fragments were collected which, although they are not sufficient for a definite determination, are said by F. H. Knowlton to have decided Fort Union affinities. Below the lower of the sandstone beds is a great thickness of beds of alternating sandstone and shale with a few thin limestone layers. Dinosaur remains, including the frill bone of a *Triceratops*, were found in this formation in the NW. ¼ sec. 4, T. 42 N., R. 79 W. It would seem, therefore, that these beds may represent a formation in eastern Wyoming and Montana which has been called by various names, "Lance Creek beds," "*Ceratops* beds," "Hell Creek beds," etc.

Barnum Brown, in an article on the "Hell Creek beds" of Montana,[a] described a series of lignite-bearing beds below the typical Fort Union and above the "Hell Creek beds." It is possible that the dark-colored shale which conformably underlies the Fort Union in the township under discussion may represent this same lignite-bearing formation. If so it is doubtful whether the sandstone ridges belong with the upper shale or with the *Ceratops*-bearing beds below. In passing northward along the base of the mountains the sandstone ridges become less and less conspicuous until they seem to give place to shale and are not observed as sandstone in the exposures west of Trabing.

Numerous plant fragments and some imperfectly preserved leaves were found in the beds underlying the Kingsbury conglomerate member, but unfortunately these were not adequate for a positive age determination.

TERTIARY ROCKS.

FORT UNION ("DE SMET") FORMATION.

The Kingsbury conglomerate member of the Fort Union formation is one of the most conspicuous and prominently exposed rock divisions in the Buffalo region. It takes its name from Kingsbury Ridge, a prominent topographic feature about 6 miles southwest of Buffalo, near the Klondike-Hazleton road. Here it is characteristically exposed and probably attains its maximum thickness. It is also well exposed on Rock Creek, northeast of Buffalo, and still farther north beyond the area covered by this report. Darton treated it as an independent formation, although he stated that it was probably developed out of the "De Smet" formation. That the conglomerate is a member of the Fort Union formation there seems no longer any doubt, and it will be so treated in this report.

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[a] The Hell Creek beds of Montana: Bull. Am. Mus. Nat. Hist., vol. 23, 1907, p. 834.

The conglomerate is composed of water-rounded gravel and bowlders, derived from the older sedimentary rocks of the adjacent mountain range and including also specimens of the granitic core of the range. So far as observed none of the basic dike rocks from that region are to be found in these beds. Among the pebbles identified are coarse red or gray granite; flat pebbles characteristic of the Deadwood (Cambrian) formation; brecciated and weather-pitted fragments or pebbles of the Bighorn (Ordovician) limestone; massive, crystalline rock of the Madison (Mississippian) limestone, containing numerous crinoids and spirifers; and other limestones, sandstones, and shales of the later formations, which are not so clearly identifiable as those of the older rocks. These pebbles are cemented in a coarse sandy matrix, and seem in their present state to have been laid down in channel deposits of exceedingly irregular bedding. The conglomeratic strata, which are in many places thick and massive, are interstratified with finer-grained, more uniformly bedded layers of sandstone and shale, dull greenish gray or drab in color, much resembling the rocks of the underlying somber-colored beds. In many places the conglomerate, even where forming prominent ledges, constitutes but a fractional part of the actual strata represented, the coarse débris resulting from its disintegration covering and concealing the softer beds.

The Kingsbury conglomerate member is evidently a shore, delta, or alluvial-fan deposit. It is clearly unconformable with the underlying formations, as its outcrop transgresses obliquely across them and its dip is somewhat discordant with that of the adjacent beds. Its deposition, therefore, appears to have followed or to have marked the culmination of a period of uplift and denudation at this particular locality and is thought to represent the erosional activity awakened at one of the more important stages of uplift of the Bighorn Mountains. The transition from the Kingsbury conglomerate to the finer sediments overlying it is by no means an abrupt one. Local beds of conglomerate, apparently of lenticular form, occur throughout a considerable thickness of strata, perhaps even thousands of feet above the main conglomerate mass.

To the north and also to the south the Kingsbury conglomerate member fingers out and disappears and the normal Fort Union ("De

Smet") strata succeed the dark shale of the Piney formation without sign of break between them. The Fort Union age of the Kingsbury conglomerate now seems very well determined by stratigraphic and paleontologic evidence.[a]

The shale and sandstone of the Fort Union ("De Smet") formation are prevailingly light yellow in tone, in more or less decided contrast to the dark shale of the Piney below. However, somber-colored shale occurs in the Fort Union at many localities, especially in association with coal beds, and in places it is necessary to examine a considerable exposure to distinguish the two formations. The Fort Union consists for the most part of shale and fine-grained sandstone, alternating here and there with thinner beds of calcareous sandstone that are commonly fossil bearing. Most of the valuable coal beds of the Buffalo region occur in the Fort Union ("De Smet") formation.

In the immediate vicinity of Buffalo, as already stated, the shale and sandy beds interstratified with the Kingsbury conglomerate member are of a dull-greenish cast, weathering to a drab or even yellowish clay or sand when dry. They are thus indistinguishable in appearance from much of the underlying Piney formation, but, as a rule, the Fort Union does not present the peculiar banded appearance, due to the alternation of light and dark shales, so characteristic of the Piney formation. Of these duller-colored strata of the Fort Union, there is a rather uncertain thickness below the principal coal-bearing group. An estimate based on observations along a section extending from Rock Creek to a point near Lake De Smet seems to indicate that there are about 2,000 feet of beds above the Kingsbury conglomerate member and below the lowest important coal of the Ulm coal group, as represented at the local coal banks or mines at the southwest side of the lake.

The coal-bearing portion of the Fort Union in the Buffalo region includes the upper 600 or 800 feet of the section as represented in the detailed stratigraphic sections made during the present investigation and published in this report. The coal is described in detail on pages 153–169.

Silicified trees are of common occurrence in association with the coal-bearing beds. They afford evidence of the climatic conditions and indicate rapidity of deposition during the period in which they and the coal beds were laid down.

The occurrence of surficial deposits of sand and gravel that cover the terraces along the base of the mountains has been noted under the heading "Topography." These deposits occupy very considerable areas in the Buffalo field, and in many places mask the underlying rock formations continuously for miles, practically preventing any direct study of the bed-rock structure or strata.

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[a] Stanton, T. W., "*Ceratops* beds" of Wyoming and Montana: Proc. Washington Acad. Sci., vol. 2, No. 4, 1909, pp. 265–268. Knowlton, F. H., Stratigraphic relations and paleontology of the "Hell Creek beds," "*Ceratops* beds," and equivalents, and their reference to the Fort Union formation: Proc. Washington Acad. Sci., vol. 2, No. 3, 1909, pp. 209, 212.

ROCK STRUCTURE.

The rock structure of the Buffalo coal field is comparatively simple. The strata of the plains are practically horizontal or have dips so low that they are in places difficult to detect. Along the eastern flank of the Bighorn Range, however, the coal-bearing strata are upturned sharply, their outcrops occupying a comparatively narrow strip of territory along the base of the mountains. To a large extent details of the major structure are concealed by the outwash deposits of gravel and sand along the mountain foot. The structure where revealed, however, shows the fold to be fairly uniform, but broken here and there by faults of considerable extent. With the older, more sharply folded strata this report has little to do, for the coals are confined to the younger and relatively flat-lying rocks of the plains. The dips in the later formations are generally slight, but are important, as bearing on the extent and position of the valuable coals.

By a comparison of accurately determined altitudes, based on United States Geological Survey bench marks, of certain coal beds along Clear Creek between the mouth of Piney Creek and Buffalo, the dip of the rocks to the northeast is found to average but a fraction of a degree. This dip is far too slight to be recognized in any particular locality or outcrop, and is obscured by the creep of rocks on many of the steep slopes. On the east side of Lake De Smet the dip is too slight to be observed, but at the coal bank on the southwest side of the lake the beds dip 4½° away from the mountains, with a strike of N. 45° W. The dip increases toward the southwest, and near the corner of the township it is 25°. In sec. 3 of the township west of Lake De Smet a dip of 10° was observed, the strike being the same as that near the lake. Along the western shore of the lake, especially near the north end, occur several parallel ridges of slag, which correspond in direction with the strike of the beds. These ridges apparently represent the outcrop of coal beds at the Healy horizon, and the straight course and narrowness of the band of slag seems to indicate that the beds at this place dip more or less. No slag occurs southwest of this locality. The coal beds below the Healy do not, as a rule, form noticeable slag.

An inspection of the map will show that a line drawn along the southwest side of Lake De Smet and parallel to its long axis corresponds to the strike of the rocks in that locality, and if continued southeastward to the southern border of T. 50 N., R. 81 W., in general marks the western limit of the burned area. From that point on, the boundary of the slag swings a little more to the eastward, north of the Bilderbach Lakes. These facts may be significant of a structure that has not yet been determined from the observed bed-rock exposures.

Southeast of the Clear Creek valley at Buffalo, in secs. 16, 21, 22, and 27, T. 50 N., R. 81 W., several parallel ridges of slag similar to those near Lake De Smet mark the limit of the burned area. They are approximately on the line of strike of the beds at Lake De Smet. Slags from several different coal horizons are here so intermingled that it is difficult to make accurate determinations of the amount of the dip or the identity of the individual beds. The dip, if any, is but slight. A mile to the west, in sec. 18, a dip of 1½° NE. was observed on a bed of carbonaceous shale. West of this point the observed dips are low for about 6 miles, but in sec. 30, T. 50 N., R. 82 W., the beds are upturned sharply and within a mile stand almost vertical.

Southeast of Lake De Smet, in sec. 2, T. 51 N., R. 82 W., a dip of 10° 20′ was observed in a coal bed taken as representing the Walters coal. From that point for some distance southeastward the slag beds are so confused that no dip determinations could be made. Just east of Buffalo there appears to be a gently folded syncline, for in the Munkre and Mitchell mines the coal beds dip at low angles to the southwest, while at Buffalo and north of Buffalo the dips are to the east. About 2½ miles east of Buffalo the slags of the Healy and higher coal beds cease in a rather abrupt escarpment, but no marked dip was observed there.

In secs. 17, 20, and 29, T. 49 N., R. 80 W., occur two shallow ponds. Each depression is opposite a small tributary of Crazy Woman Creek and is separated from the Crazy Woman Creek drainage basin by a very low divide. In sec. 8 the rocks dip to the northwest and in sec. 21 to the east. There appears to be a low anticline just east of the lakes, its axis trending about north and south. The lakes themselves seem to occupy the former heads of the two valleys above mentioned, as if the drainage had been interrupted by the warping of the strata after the valleys were formed. In the township west of the lakes the dips are low and the surface so covered that but little is revealed of the structure.

Along Crazy Woman Creek at intervals for 25 miles below Trabing a coal known as the Dry Creek bed outcrops at water level, showing that the dip of the rocks to the northeast, although locally undulating, is on the average equivalent to the fall of the stream. Five miles west of Trabing, however, the base of the Fort Union is brought to the surface and the underlying dark shale of the Piney formation is exposed, showing a dip of 12°. The ridge formed by the upturn of the strata can be seen extending outside of the area studied. To the south it traverses T. 47 N., R. 81 W., with a strike of N. 27° W.

and dips of 6° to 8°. The ridge is formed chiefly by portions of the Piney formation. It appears to extend continuously southward to Powder River, which it crosses below the mouth of South Fork. From that point it turns somewhat toward the east, crossing the southern portion of T. 43 N., R. 79 W., and continuing southeastward along the periphery of a broad dome or anticline which occupies the general region drained by Salt Creek.

THE COAL.

QUALITY AND PHYSICAL PROPERTIES.

The coal of the Buffalo field should probably be classed as subbituminous, although in character it is not far removed from lignite. It differs from lignite in color, texture, and calorific value. Its color is dark brown or even black, in contrast to the more woody brown of lignite. Although the original grain of the wood is to be observed in much of the coal, the cellular structure is not so distinct as in lignite and in some beds or parts of beds is lacking entirely. The coal is more brittle than lignite, breaking with a conchoidal fracture. Its calorific value averages about 10,000 British thermal units; this is somewhat in excess of that of the lignite of North Dakota, which averages only about 8,400 British thermal units. It may be observed that the more woody layers of the coal, dark brown when first mined, quickly blacken on exposure and appear to lose much of their woody texture. The coal in this dried condition is brittle and, when freshly broken, lustrous black in color. It breaks as readily across the grain of the original wood as it does parallel to it. On continued exposure, however, the coal loses its luster and finally crumbles or "slacks" to a fine powder.

Small masses of resin are embedded in the coal at many places and it is reported that some of them are several inches in diameter. From this occurrence of resin and the amount of coal that shows evidence of woody structure it seems probable that the greater proportion of this coal was formed from tree trunks rather than from the finer deposits of a bog. The occurrence of silicified logs and tree stumps in many of the beds helps to substantiate this view. The logs are embedded in the coal, mostly in horizontal positions. In some cases it is evident that part of the log was changed to coal while other parts were silicified. The occurrence of petrified logs is not at all uncommon in the sandstone and shale above the coal beds. Some trunks of trees are standing in their original positions half covered by coarse sandstone formed from the sand which originally buried them. They range in diameter from a few inches to 3 or 4 feet.

The coal beds of this field range from thin seams of only a few inches to heavy beds over 30 feet thick. The thickness of some of the beds is comparatively constant over broad areas; that of others varies widely. However constant in thickness a bed may be over a large area, it is evident that toward the limits of the ancient marsh in which the coal was formed the coal must be expected to change in thickness and quality and finally to end entirely.

The various beds of coal in the section differ in quality as well as in extent and continuity. A coal clean at one point may be continuous with and merge into a bony coal or carbonaceous shale which is worthless, this difference being due apparently to a difference of conditions in the marsh at the time of formation of the coal, changes in the character of vegetation, the introduction of foreign matter by water currents, etc. In certain places along the outcrop of a coal bed is observed a thin parting of shale, which thickens in passing along the strike, separating the coal bed into benches in such a manner as to render worthless a bed that in other localities is valuable.

Although a coal bed may change greatly in character from place to place, as has been observed, its horizon may usually be recognized and the interval between it and the next important bed above or below may be determined. In many cases this interval seems to be constant and may be used in identifying beds in different portions of the field. The constancy of such an interval is probably the result of the uniform rise or fall of water level with respect to a low-lying land surface over a wide territory and the consequent uniform horizontal distribution of the material laid down below and filled up to the temporarily established water level.

CHEMICAL ANALYSES.

Owing to the location of this field at a distance from lines of transportation there is little demand for its coal and only a few mines have been opened to supply fuel for local consumption. On account of the scarcity of working mines it was impossible to procure many samples of coal for analysis. In the following table are given the analyses of the samples that were collected, followed by a description of the location and the conditions at the time of collection. Each sample was obtained by cutting a channel across the coal bed or the particular bench of coal to be sampled, and pulverizing and quartering the coal thus procured. The samples were sent to the chemical laboratory in sealed galvanized-iron cans.

Analyses of coal samples from the Buffalo coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6469	NE. ¼	26	51	82	19′	Upper bench 4′ 8″.	20.5	As received....	26.8	32.8	27.9	12.47	0.64	6.04	42.72	0.60	37.53	4,080	7.344
								Air dried......	7.9	41.3	35.1	15.69	.81	4.73	53.74	.75	24.28	5,132	9,238
								Dry coal.......	....	44.8	38.2	17.03	.87	4.18	58.34	.82	18.76	5,572	10,030
								Pure coal[a].....	....	54.0	46.0	....	1.05	5.04	70.31	.99	22.61	6,715	12,087
6470	NE. ¼	26	51	82	19′	Lower bench 6′ 7″.	22.9	As received....	29.0	29.1	34.7	7.21	.39	6.53	44.64	.50	40.73	4,237	7,627
								Air dried......	8.0	37.7	45.0	9.35	.51	5.17	57.90	.65	26.42	5,495	9,891
								Dry coal.......	....	41.0	48.8	10.16	.55	4.65	62.92	.70	21.02	5,972	10,750
								Pure coal......	....	45.6	54.4	....	.61	5.18	70.04	.78	23.39	6,647	11,965
6410	SW. ¼	36	51	82	18′	Middle bench 6′.	19.9	As received....	28.0	29.7	32.8	9.47	.74	6.40	43.84	.60	38.95	4,212	7,582
								Air dried......	10.1	37.1	41.0	11.82	.93	5.23	54.73	.75	26.54	5,258	9,464
								Dry coal.......	....	41.3	45.5	13.15	1.03	4.57	60.85	.83	19.57	5,847	10,525
								Pure coal......	....	47.5	52.5	....	1.19	5.26	70.06	.96	22.53	6,732	12,118
6434	SE. ¼	3	52	82	2′ 6″	Upper part......	21.2	As received....	29.4	32.0	35.1	3.5	.31	....	....	....	....	....	....
								Air dried......	10.4	40.6	44.6	4.4	.39	....	....	....	....	....	....
								Dry coal.......	....	45.3	49.8	4.9	.44	....	....	....	....	....	....
								Pure coal......	....	47.6	52.4	....	.46	....	....	....	....	....	....
6435	SE. ¼	3	52	82	4′ 6″	Lower part......	20.6	As received....	28.4	31.0	34.1	6.48	.72	6.39	46.22	.73	39.46	4,443	7.997
								Air dried......	9.8	39.1	42.9	8.16	.91	5.17	58.21	.92	26.63	5,596	10,073
								Dry coal.......	....	43.3	47.6	9.05	1.01	4.52	64.55	1.02	19.85	6,205	11,169
								Pure coal......	....	47.7	52.3	....	1.11	4.97	70.97	1.12	21.83	6,822	12,280

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

6469 (Pl. X, 18). From the bench above the one at present worked in the Mitchell mine. The upper part of this bench is 1 foot 8½ inches thick, the lower part 2 feet 8 inches; the two parts are separated by 2 inches of bone, which was not included in the sample. The sample was taken from the wall of the slope near its foot. The coal had been exposed to the air of the mine for some months, but as there was considerable moisture present the face of the bed was as firm as when freshly mined. About 3 inches of the face was removed before the sample was cut. The cover above the coal at this point is about 100 feet thick and consists in great part of coal and coaly shale beds.

6470 (Pl. X, 18). From the bench at present worked in the Mitchell mine. This bench consists of four parts whose thicknesses, in descending order, are 3 feet 3 inches, 11 inches, 7 inches, and 1 foot 8 inches. The thin shale partings between them were thrown out in taking the sample, which was cut about 20 feet north of the foot of the slope. The mine had been opened the year before, but coal had been mined at this particular place only a few days before the sample was taken. The face of the coal showed no sign of weathering and no moisture was seen at this place. It is believed that the coal was practically unweathered. There is about 120 feet of cover above the coal.

6410 (Pl. X, 19). From the bench at present worked in the Munkre mine. The coal bed is 6 feet thick and carries a thin bone parting in some parts of the mine. This is an old mine, but the sample was obtained from a face of coal which has been worked recently about 200 feet from the foot of the slope. There is about 85 feet of cover at this point, consisting of shale and coal beds with a little alluvium at the surface. No moisture was to be seen and it is believed that the coal was practically unweathered.

6434 (Pl. X, 9). Represents an upper bench, 2 feet 6½ inches thick, of a coal bed exposed in the bank of a coulée from which coal is obtained for local use. This coal is under about 8 feet of cover, which is for the most part alluvium. Coal from this place had been mined on the day before the sample was taken, but the face of the coal had already begun to check. About 3 inches of the surface was removed before the sample was taken. Although the coal appeared hard and bright, it seems probable that changes had taken place in it due to long exposure to surface conditions. This description applies also to sample 6435.

6435 (Pl. X, 9). From lower part of same bed as sample 6434. Several thin shale partings are present, as shown on Plate X. These were thrown out and the sample was obtained from the three parts of the bench, 1 foot 7 inches, 11 inches, and 1 foot in thickness.

BURNING OF OUTCROP.

Certain of the coal beds of the Buffalo field have burned extensively along their outcrops, baking and partly melting the rocks above them. These baked rocks are of various shades of pink, brown, red, and even purple, and form one of the most conspicuous features of the landscape. Being hardened by the heat, they resist erosion much more effectively than the unaltered soft sandstone and shale, and thus form the capping rock of many of the hills. In certain localities coal beds are at present on fire, and the phenomena of the burning, the settling of the overlying beds, and the formation of fissures may be observed in actual process of development. It seems probable that the beds take fire by spontaneous combustion. Such firing of piles of slack of subbituminous coal is of common occurrence. In nature the undercutting of coal banks by streams and the consequent caving of the coal furnishes similar slack piles, and it is not unreasonable to suppose that they take fire in a similar manner.

It should be remarked, however, that certain beds seem to have burned much more extensively than others. The Fort Union coals of the Buffalo field (the Ulm coal group as defined by Taff [a]) form marked areas of slag, but the coal beds of the Intermediate coal group, which being lower in the section are exposed farther to the northeast, are not burned to any considerable extent. The lowest coals of the Fort Union, which have been termed by Taff the Tongue River coal group, are widely burned. The coals of the underlying somber-colored shale have burned but little. All these coals are subject to practically the same conditions of climate and erosion and it seems probable that the differences in the amount of burning are due to slight differences in composition that render some more prone to spontaneous combustion than others.

Many facts are difficult of explanation, however. For example, the Healy coal is universally burned along its outcrop over broad areas to the northwest of Crazy Woman Creek, but southeast of that stream, although the same coal bed is present, it is very little burned, the creek marking the boundary between the burned and unburned areas.

CORRELATION WITH OTHER FIELDS.

As already mentioned, the coal beds of the Buffalo field belong to the group designated by Taff in the field to the north the Ulm coal group. They occur in the upper portion of the Fort Union formation. Theoretically the coals of the Intermediate and Tongue River coal groups, as defined by Taff and exposed in the fields to the east and north of Buffalo, if continuous should underlie this area. Along the base of the Bighorn Mountains the flat-lying strata of the plains are tilted slightly eastward, so that in approaching the mountains one passes across the edges of the upturned beds. It is significant that no outcrops of coal beds much below the Ulm coal group can be found in this area except in one place west of Trabing, where coals at the base of the Fort Union are brought to the surface. The margins or shores of the ancient marshes in which the coals are supposed to have been formed probably lay somewhere along the base of these mountains, and along these lines the vegetal deposits would therefore cease. In the absence of more positive data as to the extent and character of coal beds lower in the section it seems impossible to make definite statements concerning any beds lower than those exposed at the surface within this area.

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[a] Taff, J. A., The Sheridan coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 123-250.

IMPORTANT COAL BEDS OF THE BUFFALO FIELD.

There are, to speak generally, three horizons at which coal occurs throughout the Buffalo field. The lowest coal is termed for convenience the Dry Creek bed, from its occurrence along that stream. About 130 feet above this bed is the coal that is mined near the Healy ranch, which is referred to in this report as the Healy coal (*d*).[a] In some parts of the field there are at this horizon two workable beds with an interval of 50 or 60 feet between them. About 175 feet above the Healy horizon is a thick coal bed workable in some portions of the field, which has been mined to a small extent in the NE. ¼ sec. 16, T. 52 N., R. 81 W., for use at the Walters ranch on Clear Creek, and which is here termed the Walters coal. Other beds occur at intermediate horizons and are locally important. There are also remnants of higher coal beds preserved in some parts of the field.

DESCRIPTION BY TOWNSHIPS.

In describing the coals of the Buffalo field the area will be considered by townships, beginning at the northeast corner and going from east to west across the field, each tier of townships being discussed in order from north to south.

T. 53 N., R. 79 W.—The principal coal bed within this township is the Healy, which occurs at an elevation of about 4,400 feet above sea level. The bed has been removed by erosion over the larger portion of the township. Its remnants appear principally along the divide between Clear and Crazy Woman creeks. In many places, especially where the coal has been left in small patches upon hilltops, it has burned, forming a marked slag. Near the west side of sec. 20 a detailed section (No. 8)[b] was made that shows the bed to be 18 feet 6 inches thick counting the included shale partings.

About 40 feet below this bed occurs another coal that is usually over 3 feet thick. The outcrops of the two as represented on the map are practically identical, although the endeavor has been made to map the upper bed only. In the strata from 100 to 200 feet below these coals are several thin beds of coal and carbonaceous shale, none of which are known to be over 2 feet 6 inches thick and none of which form noticeable slag by burning. (*hh, ii.*)

Practically nothing is positively known concerning other valuable coals that doubtless occur in the strata below water level in this area.

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[a] Letters in parentheses refer to sections on Plate IX.

[b] Numbers in parentheses refer to sections of coal beds on Plates X and XI.

SECTIONS ON PLATE IX.

a. Sec. 24, T. 50 N., R. 81 W. Section starts at coal in bed of Dry Creek and extends to hills on the east.

b. Secs. 13 and 14, T. 51 N., R. 82 W. Section starts at the burning coal bed in SE. ¼ sec. 14.

c. Sec. 25, T. 51 N., R. 81 W. Section extends from coal exposed in dry stream bed to slag-capped hill on the east.

d. Secs. 9 and 14, T. 51 N., R. 81 W. The lowest coal shown is that reported in the well at the Healy ranch in sec. 9. Its quality is unknown. The second coal is that opened at the Healy mine in sec. 14.

e. Sec. 8, T. 51 N., R. 81 W. Section starts from bench mark 4395 at gate of Healy ranch.

f. NE. ¼ SW. ¼ sec. 3, T. 51 N., R. 81 W., and southeast into sec. 10. Section begins at level of Clear Creek.

g. Sec. 32, T. 51 N., R. 80 W. Section starts at coal in creek bank and extends southeast to slag-capped butte.

h. NE. ¼ NE. ¼ sec. 12, T. 52 N., R. 82 W. Section starts at level of Boxelder Creek.

i. NW. ¼ NE. ¼ sec. 10, T. 52 N., R. 82 W.

j. NW. ¼ sec. 8, T. 52 N., R. 82 W. Section begins at water level of Lake De Smet and extends to peak west of Kennedy ranch.

k. SE. ¼ sec. 3, T. 52 N., R. 82 W. Section starts at an opening on a coal taken to represent the Healy bed and extends to a hill one-fourth mile to the northwest.

l. Sec. 36, T. 52 N., R. 81 W. Section starts at opening on Healy coal.

m. Secs. 26 and 35, T. 52 N., R. 81 W. Section starts at creek level.

n. Sec. 24, T. 52 N., R. 81 W. Below C. N. Walters ranch on Clear Creek. Section starts at creek level.

o. Sec. 24, T. 52 N., R. 81 W. About 1 mile above Watts ranch on the east side of Clear Creek. Section starts at creek level.

p. Sec. 12, T. 52 N., R. 81 W. Section begins at water level on Clear Creek, half a mile above Copp ranch.

q. NE. ¼ sec. 1, T. 52 N., R. 81 W. The lowest coal shown is 10 feet above water level of Clear Creek below Copp ranch.

r. Sec. 35, T. 52 N., R. 80 W. The heavy coal is that about 60 feet above the Healy bed. The slag represents the "upper coal."

s. T. 52 N., R. 80 W. A general section for the eastern portion of the township. The thickest coal shown outcrops in sec. 3; the higher coals were noted in sec. 23.

t. Sec. 13, T. 52 N., R. 80 W. Section extends from the coal at Rattlesnake Springs to the slag capping the butte to the northwest.

u. T. 52 N., R. 79 W. A composite section for the western portion of the township. The highest coal shown occurs in the hill on the east side of sec. 18.

v. Secs. 3 and 24, T. 52 N., R. 79 W. A barometer section. The lowest coal shown is at creek level in sec. 30 of the township east.

w. NE. ¼ sec. 33, T. 53 N., R. 82 W. Section extends from creek level below the old Senff ranch to the peak above the road.

x. Sec. 27, T. 53 N., R. 82 W. Section extends from creek level near the Flying E ranch to the old mine shaft 1 mile southeast.

y. NW. ¼ sec. 26, T. 53 N., R. 82 W. Section extends from the "upper slag" to the monument on Monument Peak.

z. Sec. 23, T. 53 N., R. 82 W. Section extends from creek level near Collin ranch to the mine on the "upper coal," thence south to Monument Peak.

aa. SW. ¼ sec. 14, T. 53 N., R. 82 W. Section extends from mine above Collin ranch to the "upper slag" farther south.

bb. NE. ¼ sec. 14, T. 53 N., R. 82 W. Section starts at creek level.

cc. SE. ¼ sec. 12, T. 53 N., R. 82 W. Section starts at creek level.

dd. NE. ¼ NE. ¼ sec. 24, T. 53 N., R. 81 W. Section starts from bench mark 4153.

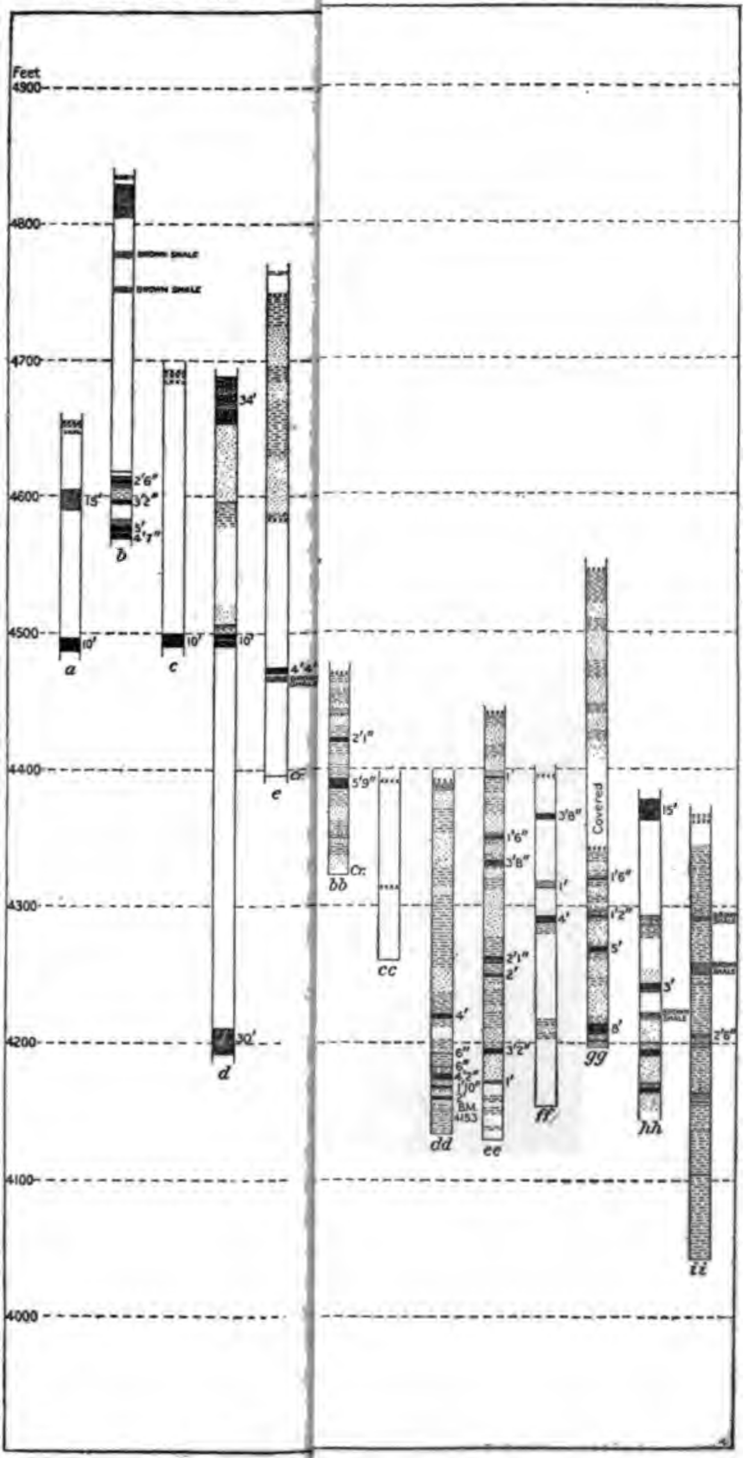
ee. NW. ¼ NW. ¼ sec. 13, T. 53 N., R. 81 W. Section starts from level of Piney Creek.

ff. SE. ¼ sec. 10, T. 53 N., R. 81 W. Section starts from level of Piney Creek.

gg. SE. ¼ sec. 5 and NE. ¼ sec. 8, T. 53 N., R. 81 W. The highest slag is that of the "upper coal."

hh. SE. ¼ sec. 4, T. 53 N., R. 79 W. Section from bed of coulée to supposed Healy coal.

ii. T. 53 N., R. 79 W. A general section for the northwestern portion of the township, compiled from a profile section from Clearmont to the "double crossing" of Clear Creek.


Feet
4900
4800
4700
4600
4500
4400
4300
4200
4100
4000
BROWN SHALE
BROWN SHALE
15'
10'
a
2'6"
3'2"
5'
4'7"
b
10'
c
34'
10'
30'
d
4'4"
Cr.
e
2'1"
5'9"
Cr.
bb
cc
4'
6"
6"
4'2"
1'10"
BM.
4153
dd
1'
1'6"
3'8"
2'1"
2'
3'2"
1'
ee
3'8"
1'
4'
ff
Covered
1'6"
1'2"
5'
8'
gg
15'
3'
SHALE
hh
SHALE
2'6"
ii

The record of the deep well at Clearmont, about 4 miles north of the township line, showing a section doubtless equivalent to that underlying most of this area, is as follows:

Record of deep well at Clearmont.

	Feet.
Sandstone and shale	195
Coal	12
Sandstone and shale	101
Coal	18

No evidence of the quality or value of the beds thus reported has been obtained.

T. 53 N., R. 80 W.—The lowest coal bed exposed in this township is represented in the western part, where a rather pronounced group of coal beds outcrops on Clear Creek, approximately at water level, but the group is so broken by shale and bony partings that it rarely contains 30 inches of solid coal, so far as it has been observed within this particular township. This bed is doubtfully correlated with the Dry Creek bed to the south.

The Healy coal, which is the principal workable bed, is approximately 15 feet thick and occurs at an elevation of about 4,400 feet above sea level. It has been removed by erosion from the greater part of the township, but some areas remain, especially in the southwestern part, and to a smaller extent in the northwest corner. In many places, especially where the coal has been left in small areas on hilltops, it has burned, forming a conspicuous slag. A still higher bed, the Walters coal, about 170 feet above the 15-foot bed, remains in a few places. It is about 35 feet thick where exposed at its full thickness, but contains a great number of shale partings which render it of doubtful value.

Several other coal beds also are exposed, but though they are of good quality none of them are known to be above 2 feet 6 inches in thickness.

T. 53 N., R. 81 W.—The coal occurring near water level along Piney and Clear creeks, at the eastern edge of this township, clearly contains workable benches at some points. At this horizon 3 feet 9 inches of coal was measured at the mouth of Boxelder Creek, near the Hogerson ranch in sec. 14 (No. 7). Approximately the same bed, 6 feet or more in thickness, has been mined in the bank of Piney Creek opposite the old Sam Dickey ranch in sec. 8 (No. 5). It may be noted that this horizon is described as of no value in the report on the township to the east. A coal from 5 to 15 feet thick which probably represents the Healy bed is recognized at a horizon from 130 to 150 feet above this lowest coal, and another bed occurs from 150 to 170 feet above the Healy. (*dd, ee, ff, gg.*)

The upper coal beds occurring above water level are largely burned along their outcrops. The uppermost bed is burned more extensively than those below and for this reason probably the greater part of the area noted as occupied by slag from this bed may be entirely devoid of this coal. In many places the underground extent of the burning is a matter of much uncertainty.

T. 53 N., R. 82 W.—Two principal beds are here recognized—the Healy and the Walters. Other coals near water level have been noted along the valley of Piney Creek and doubtless belong to the same group as that described at approximately the same elevation in the township to the east. Nothing is known concerning the coal beds that may be present below water level. The Healy bed is approximately 120 to 150 feet above water level and the Walters coal 150 to 170 feet above the Healy. The Walters coal is extensively burned on its outcrops along the summits of the higher ridges and may be completely burned out over a large part of the area occupied by the slag of this bed. In a small area in the southern portion of the township coal beds at still higher horizons remain and have been prospected to a slight extent. (*w, x, y, z, aa, bb, cc.*)

T. 53 N., R. 83 W.—No complete sections of the coal-bearing rocks were obtained in this township. But one bed of coal was noted which may be over 30 inches thick. Unfortunately, no good exposures of this bed were found in which the coal could be measured or sampled. It is represented in the northeastern part of the township by an extensive bed of heavy slag, which was traced as shown on the map. It is thought to be the bed elsewhere described as the Healy coal of the Ulm coal group. A natural bank in the NE. ¼ sec. 2 revealed coal and brown carbonaceous shale to a thickness of 15 feet or more without exposing any bench that appeared of workable quality. This is, however, but negative evidence, for the great amount of burning at or near this horizon may be interpreted as indicating the possible existence of some more valuable portion of the bed. The western limit of this and other possible coal beds is concealed by the overwash of gravel. Coal is reported by several inhabitants at Kearney to have been mined for local use from a pit in the bed of Piney Creek, about one-fourth mile below the bridge that crosses that creek near the post-office. This locality, which would be about in the NW. ¼ SE. ¼ sec. 26, was searched, and, although considerable coal of a woody, subbituminous quality was found scattered about in and near the creek, the coal bed was not seen in place and was probably covered by stream wash. An old map of Fort Phil Kearney published in Carrington's description of this territory in the pioneer days of early settlement[a] shows a bed of coal in the bank of Little Piney Creek, evidently somewhat west of the present road crossing. This coal was not found in the present work. A well at Chris Hepps's ranch, a little over one-fourth mile south of the above-mentioned locality, is also reported locally to have been drilled to a depth of 200 feet, encountering much coal through a thickness of 100 feet. These beds are thought to represent approximately the horizon of the Healy coal.

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[a] Carrington, H. B., Absaraka, land of massacre, 1878, p. 147.

Much slag was noted in the SE. ¼ sec. 36 and extending beyond the limits of this township, continuous with the one or more coals that are extensively burned about Lake De Smet. It can not be stated from the evidence at hand whether coal is or is not present at the horizon of the upper burned bed, but if valuable coal exists near stream level in Piney Creek near by, that lower bed, unburned, doubtless underlies much of the adjoining area.

Little can be said as to the possible existence of other coal beds which may exist at considerable depth and whose outcrops are buried under the terrace and alluvial cover. Valuable coals of a considerably lower horizon than those exposed here are described by Taff as existing in the Sheridan field, composing the intermediate and Tongue River coal groups. He also notes, however, that as that part of the Fort Union including these lower coal groups is traced southward the coal beds thin out and disappear as the outer fringe of the conglomerate strata is approached, presumably owing to the more abrupt changes in sedimentation at places where the coarser deposits were accumulating in strong currents of water. It seems likely that the Kingsbury conglomerate member is a broad alluvial or delta deposit which locally represents the coal-bearing strata of adjoining fields and the extent of which, beyond the base of the mountain mass, is very uncertain.

T. 52 N., R. 79 W.—As in the township to the west, three principal coal beds are here represented. The highest occurs at an elevation of 4,650 feet above sea level. It has been almost entirely removed by erosion. One exposure was found in the eastern part of sec. 18, where the coal measured about 9 feet (*u*). If this is to be correlated with the Walters coal in the township to the west, the bed evidently thins toward the east.

The only important beds in the township are the two at altitudes of 4,530 and 4,470 feet, which are taken to represent the general horizon of the Healy coal. Exposures of the two beds one above the other were found in the NE. ¼ sec. 21. They are both of workable thickness and quality. A good exposure of the lower bed occurs in the NW. ¼ sec. 3 (No. 16) and another near the south line of sec. 30. The two beds occur also near the east line of sec. 1. Their thickness varies but is everywhere more than 3 feet. They do not, however, form marked areas of slag in this township, although they are in many places burned to a slight extent. Owing to the character of the surface and the absence of burning it was impossible to trace a continuous outcrop of the coal, and for purposes of classification dependence must be placed on the contours with some allowance for possible errors in vertical control.

Numerous other beds of coal occur in this township, especially in the lower part of the stratigraphic section. It is thought, however, that none of them are constantly over 30 inches in thickness. They are too thin, too poor in quality, or too variant to be considered valuable.

According to R. W. Stone, as already stated, a 5-foot bed of coal outcrops at the level of Crazy Woman Creek, about the middle of the township east of this. It should be stated, however, that this bed seems to thin toward the west. Along Wildhorse Creek, 18 miles farther east, it varies from 8 to 30 feet in thickness, and along Clear Creek it seems to be represented by a bed which is not over 2 feet thick. Still lower valuable beds outcrop on Powder River above and below Arvada, 9 miles northeast of this township.

In the deep well at Clearmont, 9 miles north of this township, a 12-foot bed of coal is reported at 195 feet and an 18-foot bed at 308 feet; these beds may extend continuously underneath this area.

T. 52 N., R. 80 W.—There are three beds of coal that deserve attention in this township. The highest, which is here termed the Walters coal, occurs at an altitude of 4,650 feet and where not removed by erosion has been for the most part burned. It is from 25 to 30 feet thick, but contains many bony seams and appears to vary much in quality from place to place.

At 120 feet below the bed just described occurs another, which, as measured in sec. 35, has a thickness of 13 feet (*r*). It is of good quality. Several exposures of this bed were found in the southeastern part of the township on the northeast flank of the divide, but in the northwestern part of the township no measurements were obtained, although several sections indicate coal or slag at this horizon.

Sixty feet below this bed, at an elevation of 4,470 feet above sea level, occurs another coal bed of about the same thickness. The two beds were found, one above the other, in sec. 3 of the township just south of this. They are taken to represent the general horizon of the Healy coal. In sec. 11 of this township a coal bed 13 feet thick appears to correspond to the lower of the two beds (No. 14). Heavy slag commonly occurs along the outcrop of these coal beds in the township. As the two beds are but 60 feet apart and are similar to each other, it is very difficult to distinguish between them in isolated exposures.

In the NW. ¼ sec. 32 of the township to the south, 11 feet 8 inches of coal is exposed in the bed of Dry Creek. If this bed is constant it should underlie the greater part of this township, but its equivalent was not found here.

T. 52 N., R. 81 W.—The lowest coal recognized in this township is approximately at water level. It was noted in sec. 35 and also in sec. 1. As it appears to differ in thickness and quality in different places and is usually much broken by shale and bony partings, it is doubtful if it can be considered generally workable. (*n, o, p, q.*)

In the NW. ¼ sec. 35 a coal bed 5 feet 10 inches thick was discovered 70 feet above water level (*m*). It seems probable, however, that this coal is not above 30 inches thick over an extensive area.

Probably the most important bed in this part of the field is that designated the Healy coal. This is noted at altitudes of 4,450 to 4,475 feet in the southern half of the township, west of Clear Creek. The altitude of a bed thought to be the same in the northwestern part of the area is slightly above 4,500 feet. A number of sections of this bed show the thickness to be from 13 to 19 feet, including shale partings, which are, however, of minor importance. This bed has been mined for local use in the SW. ¼ SW. ¼ sec. 36, and a detailed section of the bed is given in Plate X, No. 13. It seems fair to assume that this is a workable coal bed throughout the township wherever it exists. Its outcrop is commonly indicated by a marked slag.

The so-called Walters coal, 170 feet above the Healy bed, is extensively burned in the higher ridges in this township, but where it remains unburned it is of considerable thickness. It measured 28 feet of coal, including partings in the NE. ¼ NW. ¼ sec. 3; 34 feet in the NW. ¼ NE. ¼ sec. 16; and 28 feet 4 inches in the NW. ¼ SE. ¼ sec. 18. The character of this coal bed is similar in nearly all the exposures. In each place some of the coal is evidently good. The weathering of the bed, however, brings out numerous thin bone and shale partings that break up the coal into minor benches, making the bed difficult to mine. If mined the coal would probably be high in ash. It is doubtful if the bed in many places is at present commercially valuable.

T. 52 N., R. 82 W.—The principal coal bed within this township is somewhat doubtfully correlated with the Healy coal. The slag of three higher beds is present, but the coal is for the most part completely burned. No good exposures of the higher coal beds occur, although in the hill on the south side of sec. 4 an old entry on one of these beds was observed.

One of the principal coal openings in this township is on the Healy bed in the SE. ¼ SE. ¼ sec. 3. The coal is exposed in the bed of a draw. The bed as shown in section No. 9, Plate X, contains about 9 feet of coal, excluding the shale partings. (See also *k*.)

In the SW. ¼ sec. 12 is exposed a coal bed which is supposed to be the same as that in sec. 3, just described. The total thickness of the bed is 18 feet 7 inches, but the coal is too badly weathered to permit a detailed section.

In secs. 19 and 20, on the southwest side of Lake De Smet, two workable beds come to the surface at a horizon that seems to correspond to the Healy. The beds dip 4½° NE. The interval between them was not measured but is approximately 60 feet. The upper bed is 6 feet, the lower 5 feet in thickness (No. 10). The coal in both is of good quality and has been mined to a small extent.

In the SE. ¼ sec. 1 of the township to the west at least 4 feet of coal is exposed in the bank of Shell Creek. This coal has probably been removed by erosion from portions of the alluvial flat north of Lake De Smet. No other exposures of the bed occur.

No coal beds were discovered southwest of those just mentioned near Lake De Smet. The coal beds near Arvada described by Stone and those of the Sheridan district described by Taff, were they continuous, should underlie this area and come to the surface between it and the mountains. No trace of those coal beds was found, however. The surface is partly obscured by the mantle of gravel that skirts the mountains, yet outcrops of bed rock may be found along the stream beds. It seems probable that the lower coal beds do not exist here and that they may be represented and replaced by the Kingsbury conglomerate member. (See also *h*, *i*, *j*.)

T. 52 N., R. 83 W.—No coal bed is known in this township, the southwest half of which is occupied by rocks older than the Fort Union. The strata dip to the northeast.

Slag in the northeast corner of the township (in and near sec. 1) indicates a coal bed that appears to be for the most part burned. This bed is very doubtfully correlated with the Walters coal to the east. If this correlation is correct, there should be workable coal 170 feet below this bed. Little weight should be attached to such an assumption, however, as the information is too meager to warrant much more than a guess. The outcrop of the workable coal at the southwest end of Lake De Smet would probably be exposed through a part of this area were it not concealed by the extensive gravel and bowlder beds, but that coal bed is known to vary in quality and thickness and can not be assumed to be continuously workable.

Coal was observed in the stream wash on the upper waters of Rock Creek, in the northwest corner of sec. 24. This is of a quality similar to that of the workable coals of this district, but no evidence of its source was found. It is assumed to be from some of the carbonaceous beds of the Piney formation, which are of no value in this general region.

T. 51 N., R. 80 W.—The Dry Creek coal bed is exposed along the stream of that name in secs. 22, 29, and 32 (Nos. 23, 24, *g*). In sec. 32, 11 feet 8 inches of good coal was measured. No outcrops of this bed were found in the northeastern portion of the township.

The coal elsewhere referred to as the Healy bed occurs about 150 feet above the Dry Creek bed. It measures 16 feet in the NW. ¼ sec. 16, the coal being of good quality. It underlies an area of about 6 square miles in the northern part of the township and about 2 square miles in the southern part.

A thick bed of carbonaceous shale, including some coal, represents the Walters coal in this area and is found from 150 to 170 feet above the Healy.

T. 51. N., R. 81 W.—There are two principal coal beds in this township. The lower, which is here termed the Healy, occurs at an elevation of 4,500 feet above sea level. The Walters coal is 175 feet above the Healy bed.

A good exposure of the Healy coal occurs in the NW. ¼ SE. ¼ sec. 14 (*d*). Coal is obtained here for the Healy ranch on Clear Creek. The portion of the bed exposed is 10 feet thick and the coal is of excellent quality (No. 21). An exposure of the same bed occurs in the SW. ¼ SW. ¼ sec. 36 of the township to the north, where 17 feet 6 inches of coal is exposed (No. 13). A bed taken to be the Healy outcrops in the southern part of sec. 5 and in the NE. ¼ sec. 7. Just west of the township line, between sec. 18, T 51 N., R. 81 W., and sec. 13, T. 51 N., R. 82 W., are several abandoned entries which appear to be at the same horizon. A little east of the center of sec. 25 coal appears in the bed of a draw. It is of excellent quality and has been mined to a moderate extent. It appears to be at the Healy horizon (*c*). Coal of rather poor quality has been mined from a bed exposed in a draw in the western part of sec. 36. The interval to the next slag above is 150 feet. This coal is probably somewhat above the Healy horizon.

The Walters coal appears in small isolated areas along the divide between Clear and Dry creeks. In the southern part of sec. 13 the bed was formerly worked as an open bank. It measures 34 feet in thickness, but is so broken by partings of bone that it is inferior in quality to the Healy coal.

In the SW. ¼ sec. 20 a coal bed 12 feet thick is exposed which seems to be about 50 feet below the Healy (No. 22). In sec. 9 a bed of coal 3 feet thick appears at about this horizon, but no other exposures of the bed were found. It seems not unlikely that it varies in thickness and quality.

It is reported that in drilling a well at the Healy ranch a coal bed 30 feet thick was struck at 160 feet below the flood plain of Clear Creek. A few miles down Clear Creek, in the next township north, a coal bed at this horizon comes to the surface, but is much broken by shale and is of little value. (See also *e, f.*)

T. 51 N., R. 82 W.—The slag that occurs along the east township line probably represents the Healy and Walters coals, the latter being 175 feet above the former. In many places the slag beds are so badly confused by slumping that it is difficult to distinguish the different horizons. Just east of sec. 13 several entries have been opened on a bed of coal, which is taken to be the Healy. In the SE. ¼ sec. 23 an entry has been opened at about the same horizon. This coal is said to have been rather poor in quality. In the SE. ¼ sec. 14 a series of beds at the same horizon is exposed in a coulée (No. 17, *b*). One of the beds is burning to a slight extent.

The Mitchell mine, in the NE. ¼ sec. 26, was opened in 1907. A section of the coal beds exposed in the slope is given in No. 18, Plate X. The bed at the top of the section was first worked. It contained good coal, but is so broken by shale partings that an attempt was made to reach other beds. A series of coals was encountered, of which the lowest bed is the one at present mined. Another bed over 4 feet thick occurs 10 feet above it. The coal beds dip slightly in a direction S. 40° W. When visited the mine was putting out about 50 tons a month. The slope is 220 feet in length and has an inclination of 33° from the horizontal. It is necessary to pump 3,000 gallons of water from the mine every twenty-four hours.

In the western part of sec. 36 is the oldest mine in this township, owned by G. W. Munkre. The coal bed here mined is 85 feet below the surface. Above it are numerous beds of bony coal, said to be of no value. The coal dips slightly toward the southwest. A section is given on Plate X (No. 19). The output of the mine during the winter months is about 27 tons a day.

It is reported that on the hill just southeast of Buffalo a drill hole was put down to the depth of 185 feet and that 52 feet of coal was encountered in the last 64 feet, but none of the beds was over 2½ feet in thickness.

In the western portion of the township outcrops are obscured by extensive gravel beds, and no coal is known.

T. 51 N., R. 83 W.—So far as known no coal of value occurs within this township. In the northeast corner, however, some beds of coal and brown carbonaceous shale were found overlying the Kingsbury conglomerate member. The largest of these is in the bank of Rock Creek, near the township corner. Here one bed of coal measures about 6 feet in thickness, but is so poor in quality that it is probably of no value. Other carbonaceous beds doubtless occur in the older Cretaceous rocks of the area; but, as elsewhere stated, they are, so far as known, of no commercial value.

The rocks that outcrop in this township consist of the lower part of the Fort Union ("De Smet") and older formations. As these have a general northeasterly dip, they pass beneath and normally underlie the more valuable coal beds of this region, which occur at a horizon well up in the Fort Union formation, their base being estimated to lie from 1,500 to 2,000 feet above the Kingsbury conglomerate member. Several of the lower beds of this group are represented at the mines near Lake De Smet, about 2 miles northeast of this township, as already described.

T. 50 N., R. 80 W.—A thick bed of coal has been observed outcropping at many localities near water level on Crazy Woman Creek in this township. It is thought to represent the bed elsewhere described as the Dry Creek coal, which is well exposed near the Healy sheep pens, on Dry Creek, a short distance north of this township. The measured sections of this bed near the southeast corner of the township are shown graphically in Plate X (No. 27). As this bed appears to be workable both northwest and southeast of this township, ranging from 6 to 12 feet in thickness, and as it also outcrops in sec. 8, T. 49 N., R. 80 W., with a thickness of 6 feet, it seems fair to assume that it underlies the whole area and is also workable there.

The coal elsewhere referred to as the Healy bed occurs about 150 feet above the Dry Creek bed. Just west of the township line, in sec. 24, T. 50 N., R. 81 W., this coal is exposed in the creek bank. It is 11 feet thick and the quality is good (No. 26). The same bed outcrops in the NE. ¼ sec. 7, the NW. ¼ sec. 8, the SE. ¼ sec. 3, and the NE. ¼ sec. 10. Exact measurements were not obtained, but the bed appears to be of fairly uniform thickness. It underlies a considerable area along the divide between Dry and Crazy Woman creeks, as shown on the map.

From 150 to 170 feet above the Healy bed is found the Walters coal, which is here a thick bed composed largely of carbonaceous shale with coaly streaks and is of doubtful commercial value. Slag on one or two of the highest summits near the center of the township represents coal beds higher than the Walters coal. These are, however, completely burned out.

T. 50 N., R. 81 W.—Above the road in the NW. ¼ sec. 5 of this township several entries have been made on a coal bed just below the slag that caps the ridge. The old workings are now abandoned and no exposure of the coal was seen. On the flat in the SW. ¼ sec. 5, a slope has been sunk to a bed some 25 feet below the surface. This coal is reported to be of excellent quality and to have a thickness of about 10 feet (No. 25).

In the NE. ¼ sec. 24 a coal bed that is taken to represent the Healy occurs at creek level (*a*). It is 11 feet in thickness and of excellent quality (No. 26). In the NW. ¼ sec. 12 an exposure of a bed of bony coal occurs at almost the same horizon. These beds may be identical, but it is the opinion of the authors that one occurs a little above the other, the two being so near together that it is impossible to distinguish them in isolated exposures. A good coal appears at this horizon in sec. 25 of the township north of this.

The coal beds above the Healy coal in this area may be disregarded so far as present availability is concerned. They occupy only a small area and are for the most part burned.

About a mile northeast of this township a 10-foot bed of good coal outcrops at water level in Dry Creek. On Clear Creek a bed at the same horizon is so broken by shale partings as to be of little value, but to the south along Crazy Woman Creek this bed runs from 6 to 8 feet in thickness as far as Trabing. It seems probable that this coal underlies the township under discussion, but, as stated, it may vary in quality and section.

T. 50 N., R. 82 W.—The southwestern half of this township is occupied by rocks older than the Fort Union. Of the Fort Union itself chiefly the lower portion, which is apparently barren of workable coal beds, is exposed within the area. The strata dip to the northeast at very slight angles. The upper Fort Union coal beds occur just north and east of the township. The Munkre mine in sec. 36, T. 51 N., R. 82 W., is about half a mile due north of sec. 1 in this township. An exposure of coal over 3 feet thick outcrops less than one-fourth mile east of the southeast corner of sec. 1. A well on the Jones ranch in the center of sec. 7, T. 50 N., R. 81 W., half a mile east of sec. 12 of this township, is reported to have shown the following strata:

Section of coal beds in well in sec. 7, T. 50 N., R. 81 W.

	Feet.
Clay and gravel	20
Coal	32
Clay	5
Coal	8
Clay	4
Coal	8
Clay	1
Coal	32
Interval drilled below this, but showing no coal	50
	160

In interpreting this well record, however, it must be remembered that the thick beds of coal noted therein may not have been of workable quality and that a carbonaceous shale might easily have been interpreted as coal by a driller not experienced in the identification of workable coal. From the evidence in the adjoining townships it would seem fair to assume that at least a portion of the valley area in the northeast corner of the township may be underlain by beds of workable value.

T. 49 N., R. 80 W.—The township is underlain by the upper beds of Fort Union age, including the coal beds of the Ulm coal group as distinguished by Taff in the Sheridan district. The strata show a low dip to the southeast through the northern part of the township, although the principal workable coal bed remains approximately at water level along Crazy Woman Creek across the whole township. Some slight structural irregularity was noted east and northeast of the Bilderbach Lakes, this being apparently a low anticlinal warp separating them from the valley of Crazy Woman Creek.

A large part of the western half of the township is composed of low, broad, flat valleys and slopes covered by a white clay soil strewn with scattered pebbles and bowlders, but showing no bed-rock exposures. Beyond these lower valley lands are terrace or mesa remnants capped by heavy deposits of gravel and bowlders. Over most of this area no evidence whatever of the underlying bed rock or the coals that it may contain was to be had from a mere examination of the surface.

The Dry Creek coal is exposed at various points along Crazy Woman Creek throughout the township, as already mentioned. In the northern portion of sec. 23, 10 feet of coal was measured. The bed is of considerable thickness also on the north side of sec. 1. In the NW. ¼ sec. 8 is exposed 6 feet of good coal which is thought to represent the same bed. The slight doming of the strata in the central part of the township makes the distribution of this coal bed uncertain. Over portions of the area it has been removed by erosion and the rolling grassy surface makes the outcrop difficult or impossible to trace.

A bed of good coal that occupies small areas in the central and southeastern portions of the township is about 130 feet above the bed of Dry Creek. It is thought to represent one of the coal beds at the Healy horizon. In the SE. ¼ sec. 22, 5½ feet of good coal is exposed in this bed. In the SE. ¼ sec. 15, 5 feet of coal is exposed, but in the SW. ¼ sec. 11 this bed appears to be worthless. Because of the doming of the strata the area underlain by this coal in the central part of the township is probably not over 2 square miles. In the southeastern portion of the township the same bed was noted in the SW. ¼ sec. 35, where 5 feet of good coal is exposed.

T. 49 N., R. 81 W.—The greater part of this township is occupied by the gravel terraces that skirt the mountains. The rocks belong to the lower portion of the Fort Union formation. They dip northeastward at very low angles. So far as known only one exposure of coal occurs within the township, and this bed is but 2 feet in thickness. It occurs in the NE. ¼ sec. 35. In sec. 2 an exposure of slag occurs, but the coal by which it was formed was evidently much broken by shale partings. The valuable coal beds lie to the northeast outside the limits of the township.

T. 48 N., R. 80 W.—As in adjoining townships, the geologic structure and stratigraphy of this area are very simple. The underlying strata are of Fort Union age, including the Ulm coal group as distinguished by Taff in the Sheridan district. They lie nearly horizontal, showing at places a low dip to the east, but in the absence of accurate level data the dip can not be positively determined. The northwestern part of the township is largely covered by surficial beds of bowlders and gravel that form an upland terrace or area of rolling topography and conceal most of the bed rock. The broad bottom lands of Crazy Woman Creek are largely concealed in a similar manner by the more recent alluvial deposits. The outcrops of coal from 6 to 8 feet thick that were discovered at various places along the creek valley apparently represent an approximately continuous horizon, which is taken to be that of the Dry Creek coal bed, but its extent beyond the limits of the actual outcrops is very uncertain. East of Crazy Woman Creek the bed-rock formations are more continuously exposed but show very little evidence of coal either in outcrops or by burning. Coal reported on the Powder River side of the divide, east of this township, may correspond to the coal found in Crazy Woman Creek. This appears to give some warrant for supposing the whole area east of the creek to be underlain by workable coal.

The Dry Creek coal mentioned above is mined in the bank of the creek in the SE. ¼ sec. 30, where about 10 feet of good coal is exposed. In the SW. ¼ sec. 21 this coal appears in two benches of 7 feet and 4 feet (No. 30). In the NW. ¼ sec. 15, 10 feet of coal is exposed (No. 29), and in the SE. ¼ sec. 3, 5 feet on the same bed (No. 28). Other exposures occur along the creek at intervals throughout the township.

T. 48 N., R. 81 W.—The greater portion of this township is covered by the Fort Union formation. The beds rise gradually from northeast to southwest across the township, and in secs. 30 and 31 the underlying shale of the Piney formation comes to the surface with a dip of 10° and a strike of N. 17° W. For the most part the country is gently rolling and grass covered. Along Crazy Woman Creek marked gravel terraces are developed. No coal is exposed within this township.

In the SE. ¼ sec. 30 of the township to the east 10 feet of good coal outcrops in the bank of Crazy Woman Creek, as already described, and this bed may be traced downstream throughout the township, its dip being about equivalent to the grade of the creek. This coal bed may or may not underlie the eastern part of the township under discussion. No trace of it was found, as there are very few bed-rock exposures of any kind in this area.

In sec. 17 of the township to the south two coal beds 8 feet thick come to the surface with a dip of 7½° and a strike of N. 18° W. These beds appear to vary in thickness along the outcrop. No exposures of them were found north of Crazy Woman Creek, and it seems doubtful whether or not they are present in this township.

T. 47 N., R. 80 W.—Very few exposures of any sort occur within this township. The country is for the most part gently rolling and grass covered. The rocks are probably of Fort Union age. To judge by dip readings north and west of the area, there appears to be a slight dip to the southeast in the northwestern part of the township. For the most part, however, the rocks seem to be horizontal.

In the SE. ¼ sec. 30 of the township to the north 10 feet of coal has been worked in the bank of Crazy Woman Creek. This bed can be traced downstream throughout the township. If it is continuous southward it underlies the township under discussion, but no definite statements can be made concerning it.

In the western portion of the township to the west several coal beds from 3 to 8 feet thick come to the surface with a dip of about 7° and a strike of N. 18° W. These beds do not, however, appear to be constant in thickness along the outcrop. It is not unlikely that they vary in quality and thickness from place to place and that they underlie this township at too great depth for profitable mining.

T. 47 N., R. 81 W.—The eastern half of this township is covered by the rocks of the Fort Union formation. These rise gradually toward the west, and in the middle of the township the basal beds come to the surface with a dip of 9° and a strike of N. 18° W. Farther west the shale of the Piney formation appears below the Fort Union.

There are two groups of workable coal beds in this township, one at the base of the Fort Union and one at the top of the Piney. The best exposure of the Fort Union coals occurs in the eastern part of sec. 28 in a deep coulée (No. 36). At the base of the section exposed is a bed of good coal about 6 feet thick. Above this are a number of unimportant beds of coal and coaly shale. The bed may be traced for three-fourths of a mile northeastward, but beyond this point it is covered. No exposure of a bed comparable in thickness to this one is to be found to the southeast, and it is impossible to say how regular this coal may be in thickness and quality.

Considerably above this horizon, about three-fourths of a mile to the east, a bank has been opened in the NE. ¼ sec. 27, where 4 feet of good coal is exposed. This bed seems to be about on the strike of the line of slag hills in secs. 10 and 15 and may represent the same bed. No other exposures of the coal bed are to be found, however.

Two workable beds of coal near the top of the Piney formation are exposed in sec. 17. The upper bed contains 7 feet 6 inches of solid coal. An entry 60 feet in length has been run in on this bed, in the SE. ¼ SW. ¼ sec. 17, to supply coal for local use (No. 33). Ten feet above this bed is another one 3 feet 4 inches thick.

Some 30 or 40 feet lower in the section is a bed containing 8 feet of coal (No. 32). Although somewhat broken by shale partings, this bed is still workable.

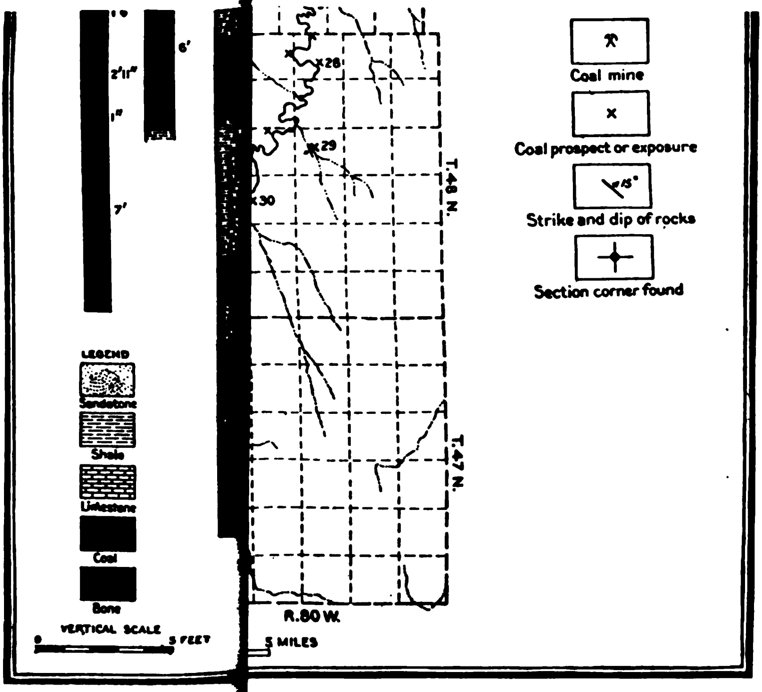
In the NE. ¼ sec. 29 and the NW. ¼ sec. 28 (No. 35) coal beds 30 inches or more in thickness were found, but they are in no way comparable to the beds above described. If they represent those coals, the beds have decreased greatly in value. In the northwestern portion of the township, along the line of strike of these coals, exposures are obscured by the alluvium of Crazy Woman Creek or by gravel.

T. 43 N., R. 79 W.—This township is situated on Powder River, 18 miles south of the area shown on Plate X. It was examined at the close of the field season, after the disbanding of the party, in anticipation of future work. It gives a general idea of the geology of a considerable belt of coal-bearing rocks which come to the surface along the flank of the Salt Creek dome in this region. As the township is outside of the area of the large map, a separate diagram from the original field sheet is here reproduced (Pl. XI).

The general succession of the rocks has been described under "Stratigraphy." On the north side of the river most outcrops are obscured by extensive gravel-covered terraces. Here the rocks appear to be for the most part horizontal, but in the NE. ¼ sec. 8 a dip of 1° NE. was observed, with a strike of N. 75° W. South of the river the beds rise gradually, with increasing dips, until they form a marked ridge extending across the southern portion of the township, in which the beds dip from 15° to 18°. Behind this first ridge is a valley and south of that still another ridge, the rocks dipping 22°. The strike in the southwestern portion of the township is N. 81° W. In following the ridge westward the strike swings somewhat toward the north.

In the SW. ¼ sec. 30 a dip of 22° was observed. It is estimated that from that point northeastward about 5,100 feet of strata are exposed. No dips were measured southwest of this point, but the beds gradually flatten in that direction. The coals are confined to a narrow belt just north of the marked sandstone ridge. Detailed stratigraphic sections of the barren strata were not made.

Coal occurs at only one horizon in this township, flanking the high pine ridge on the northeast. There are two principal coal beds 90 feet apart (Nos. 37, 38, Pl. X, 1, 2; Pl. XI). In the northern portion of sec. 36 both are good, and coal is obtained for local use from the upper bed. In sec. 26, only three-fourths of a mile northwest of the open mine, the upper bed is bony and of no value, but the lower bed


6'
2'11"
1"
7'
LEGEND
Sandstone
Shale
Limestone
Coal
Bone
VERTICAL SCALE
0
5 FEET
28
29
30
T.48 N.
T.47 N.
R.80 W.
5 MILES
Coal mine
Coal prospect or exposure
15°
Strike and dip of rocks
Section corner found

appears to be good and was formerly worked in the SW. ¼ sec. 26 for a short time (Pl. XI, 2). H. W. Davis states, however, that the coal ran so high in sulphur that it could not be used as a domestic fuel. It is impossible to trace the coal beds beyond the middle of sec. 27, for they are concealed in the Salt Creek valley and on the rolling grassy divide beyond. Beds which appear to represent the same horizon are worked in T. 44 N., R. 81 W.

There seems to be no doubt that these coal beds vary in quality and thickness. It is calculated that the upper bed is approximately 1,200 to 1,300 feet below the surface at the Davis ranch. It probably underlies all the northeastern portion of the township at about that depth, as the rocks are nearly horizontal.

THE COAL FIELD IN THE SOUTHEASTERN PART OF THE BIGHORN BASIN, WYOMING.

By E. G. Woodruff.

INTRODUCTION.

This paper is a preliminary report on the coal field in the southeastern part of the Bighorn Basin, Wyoming,[a] extending from No Wood Creek, on the north, around the southeastern point of the basin to Bighorn River.

During the summer of 1907 C. W. Washburne examined the coal fields on the east side of the basin from a point north of the Montana line as far south as No Wood Creek, and during the same time the writer examined the coal fields on the west side from the Montana line to Bighorn River. The field described in this report lies between the two just mentioned and the work in it completes the study of the coal beds of the Bighorn Basin. All of this work was done under the immediate supervision of C. A. Fisher, who had previously made a reconnaissance survey to obtain data for a report on the geology and water resources of the region.[b]

Max A. Pishel served as principal assistant in the field and rendered valuable services in the office in compiling data for the map. Jay H. Cather and Roy L. Nelson also assisted in the field work and much of the value of this report is due to their intelligent cooperation. The purpose of the work was to examine the coal beds and to determine their situation with respect to the points located by the land surveys of the area, in order that the public land containing coal might be segregated from noncoal land and a value placed on each legal subdivision containing a workable bed of coal. As a basis for this classification the coal beds and geologic formations were studied in the field and their position and extent were shown on a map made during the progress of the work. A copy of the map is included in this report as Plate XII. The relative positions of objects shown on this map were determined by horse pacing in the northern part of the field and by a system of triangulation by plane table in the southern part.

Marked land corners were found to be lacking except along No Wood Creek and Bighorn River, where resurveys have been made.

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[a] A detailed report on the coal beds of the Bighorn Basin is now in course of preparation, to be issued later as a separate bulletin.

[b] Fisher, C. A., The geology and water resources of the Bighorn Basin, Wyoming: Prof. Paper U. S. Geol. Survey No. 53, 1906.

As a result of this condition the outcrops of coal beds can not be accurately located with regard to land lines. It should be borne in mind, therefore, in consulting the map, that locations in the interior of the field are only relative and not determined with reference to land corners.

LOCATION AND EXTENT OF THE FIELD.

The coal-bearing rocks outcrop in a belt 6 to 12 miles wide, extending southeastward from the lower course of No Wood Creek along Sand and Cottonwood creeks to the east side of the "Honeycombs," then turning west across No Water Creek to Bighorn River. The field contains about 600 square miles. It is limited on the west and northwest by badlands and on the east and southwest by the dissected plains adjacent to No Wood and Kirby creeks. The region partakes of the character of both provinces—badlands on one side and broken plains on the other. The extent of the field is shown on the map (Pl. XII), and its location in a larger area by the smaller index map on the same plate.

TOPOGRAPHY.

The accessibility of coal and the ease with which it is transported from any region depend on the topography; hence a detailed description of the surface features is given. Erosion is rapidly progressing everywhere, forming deep, narrow valleys, across which wagon roads are maintained with difficulty. In the northern part of the field Sand Creek follows the strike of the beds from the southern part of T. 47 N., R. 91 W., to No Wood Creek, in a narrow gorge joined by many small branches flowing in deeply cut channels from the moderately dissected regions on either side. One wagon road from Bonanza to Worland crosses this coulée in the northwestern part of T. 48 N., R. 91 W., and another from Tensleep to Worland extends across the badlands near the head of the stream. On both of these roads the grades are so steep that heavy loads can be hauled over them only with great difficulty.

Cottonwood Creek, which drains the region east of Sand Creek, has a number of branches in the badlands in T. 46 N., Rs. 89 and 90 W., that join near the north line of the township to form the main channel. From the junction of these branches the creek flows northward in a broad, moderately open valley. The Worland-Tensleep road crosses this creek 1½ miles north of the junction of the main branches. Another wagon road from the north extends up the valley to the small coal mine in sec. 34, T. 47 N., R. 90 W., and thence over the divide to Little Cottonwood Creek. The road to Tensleep is very hilly, but the one in the valley crosses only a few hills and most of these are short.

The head branches of Little Cottonwood Creek have cut the area north and northwest of Tensleep Butte into sharp ridges, spurs, and points separated by narrow V-shaped valleys. Though no wagon road crosses this area, it would be possible to construct one from Bud Kimball Draw leading through the badlands west of Tensleep Butte and along a divide into the valley of Cottonwood Creek.

Bud Kimball Draw and Buffalo Creek rise on the edge of the badlands locally known as the "Honeycombs" and extend eastward across the area. There is a narrow belt of badlands about the heads of these streams along that part of the west side of the field, but elsewhere the topography is that of a moderately dissected plain crossed by coulées or narrow steep-sided gorges. This portion of the field can be traversed with moderate ease along the streams or divides, but passage across them is difficult. The only wagon road leading to this district enters from the east and terminates in the district; the badlands on the west and coulées difficult to cross in a north-south direction prevent access over roads from other directions. One of the minor roads follows Bud Kimball Draw from the valley of No Wood Creek to the mine at the head of the draw and has a northeast branch to Tensleep; another leads along the divide between Buffalo Creek and Bud Kimball Draw to coal prospect No. 6, near North Butte.

The southeastern part of the field is traversed by No Water Creek and its branches. The name aptly describes the character of this stream, though at times the flood water from a large area finds its way to Bighorn River through its channel. The stream enters the field from the southeast in T. 44 N., R. 90 W., and continues in a northwest course for about 15 miles. The branches from the southwest are short and steep from their source along an escarpment of northeastward-dipping beds; the branches from the northeast are longer and have a smaller gradient. A road with many short, steep grades follows the valley in general, but is forced away in many places by deep, narrow gorges cut by the branches where they enter the main channel. This road passes the No Water mine and furnishes a difficult outlet for the coal. Other roads enter the No Water Valley from the area across the divide to the east.

Kirby Creek drains the southwestern part of the field, and a few short, steep-sided ravines rise in the high rugged Winchester Hills and extend directly to the narrow valley of Bighorn River. Wagon roads extending down the Kirby Creek valley and coming into it from the north lead to fords at several places along the river.

The workable coal beds of this field are not easily accessible, because of the rough character of the country as described above. They lie in badlands or slightly dissected plains, and, with the exception of the beds near Bighorn River, are more than 10 miles from market. The region is uninhabited except along No Wood Creek and Bighorn River, and the only running water found throughout a great part of the area is derived from alkaline springs. One well in the valley of Buffalo Creek contains a small quantity of slightly alkaline water, and another in the valley of Cottonwood Creek at the crossing of the Worland-Tensleep road furnishes about a barrel a day. No railroad crosses the coal field, though a branch of the Chicago, Burlington and Quincy Railroad runs along Bighorn River, on the western edge of the area mapped, to Kirby. In many places the wagon roads are poor and have uneven gradients.

GEOLOGY.

STRATIGRAPHY.

The only geologic report on this field is that of C. A. Fisher,[a] who recognized that the coal-bearing rocks were susceptible of subdivision into several formations, but the time at his command and the nature of his work demanded the mapping of only broad divisions.

As recognized by the present writer, the order, age, character, and thickness of the formations are shown by the following table:

Coal-bearing and associated formations in the southeastern part of the Bighorn Basin.

System.	Group.	Formation.	Character.[b]	Thickness (feet).
Tertiary.		Wasatch formation.	Sandy shale and conglomerate, gray, pink, and yellow colors alternating.	Not wholly exposed in this field.
		Unconformity.		
		Fort Union formation.	This formation occurs in two divisions; the upper member is yellowish tan, gray, and lavender colored sandy shale and sandstone; the lower member is yellowish tan and rusty colored, slightly sandy shale, with lenses of coal locally developed in the lower part.	1,200 to 2,900
		Unconformity.		
Cretaceous.	Montana.	Undifferentiated Montana.	These rocks may be separated into three divisions. The upper member consists of gray and yellowish tan sandy shales, alternating with brown carbonaceous shale and coal beds. These where recently eroded form a somber-colored banded exposure. The middle member consists of very soft yellow sandstone and sandy shale and soft sandstone concretions. This member thins rapidly to the west. The lowest member is made up of soft gray sandstone, slightly cross-bedded, containing occasional thin layers of mud-ball conglomerate and macerated carbonaceous material.	500
		Claggett (?) formation.	Yellowish-tan massive thick-bedded sandstone and tan-colored sandy shale, and a few beds of gray and brown sandy carbonaceous shale.	200 to 300
		Eagle (?) sandstone.	Yellowish-gray massive thick-bedded sandstone and yellowish-gray sandy shale Beds of carbonaceous shale and coal occur here and there in the sandy shale member.	100 to 200
		Colorado shale.	The upper part of this formation is tan-colored thin-bedded sandstone and sandy shale.	Not wholly exposed in this field.

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[a] The geology and water resources of the Bighorn Basin, Wyoming: Prof. Paper U. S. Geol. Survey No. 53, 1906.

[b] In the eastern part of the area all these formations are more shaly than elsewhere.

The lines between the formations given in the above table are based on a consideration of both stratigraphic and paleontologic evidence. The beds have been examined by T. W. Stanton at several points between the type localities in Montana and the Bighorn Basin, and by C. A. Fisher at closer intervals in the same area, and have been traced from Bridger, Mont., in the Clark Fork valley, to Basin, on Bighorn River, by C. W. Washburne. Mainly on stratigraphic evidence these observers report beds which probably represent the Eagle and Claggett, and they find some indications pointing to the presence of the Bearpaw and Judith River, though the evidence for exact correlation of these upper rocks with formations recognized elsewhere is insufficient. T. W. Stanton and F. H. Knowlton visited the field discussed in this report and have since examined the fossils collected during the progress of this work. They report that the fossils are not sufficiently distinctive to prove with certainty that the Eagle sandstone and Claggett formation are represented, and are still more doubtful concerning the correlation of the upper beds. Some species found elsewhere in the Judith River formation occur in the lowest members of the undifferentiated Montana, but they are not sufficiently distinctive to prove that these beds are of Judith River age. A consideration of the combined stratigraphic, lithologic, and paleontologic evidence, however, points to the presence of the divisions of the Montana group given in the table. The identification of the Fort Union is based on fossil plants, which have been identified by F. H. Knowlton as undoubted Fort Union forms. Some species of fossil plants found in these beds also occur in the "Laramie" of neighboring regions, but no fossils clearly distinctive of that formation were found in the southeastern part of the Bighorn Basin.

The upper part of the Colorado shale is exposed on the eastern and southern borders of the area mapped on Plate XII. It is a mass of yellowish, slightly ferruginous, thin-bedded sandy shale and shaly sandstone, 200 to 300 feet thick. North of Kirby Creek it contains lenses of massive sandstone 20 to 30 feet thick and several miles long. The middle part of the formation, which is exposed just outside of the area mapped but passes beneath it, consists of several hundred feet of dark-colored shale, which grades upward into the rocks of the upper part, just described.

The Eagle(?) sandstone consists generally of two yellowish-gray massive members, one at the top and the other at the bottom of the formation, and a thick bed of sandy shale between them, but locally three or four beds of sandstone and intervening shale are present.

Where it is exposed just east of Bighorn River, near Kirby, the formation is composed of a massive yellowish-tan sandstone 50 feet thick at the bottom, overlain by 80 feet of gray sandy shale containing beds of carbonaceous matter and two coal beds of workable thickness, and at the top a massive yellowish-gray sandstone 60 to 75 feet thick. The formation contains similar members where it is exposed at the north end of the field near No Wood Creek, but toward the middle of the area the sandy beds lose their massive character and become more shaly, until the formation is changed entirely from its typical aspect, the carbonaceous shale becoming less abundant and the coal beds disappearing.

The Claggett(?) formation lies conformably above the Eagle(?) sandstone, but differs from it in lithologic character. Near Bighorn River it consists of yellowish-tan massive beds, but to the east the sandstone gradually becomes shaly until the whole formation is composed of yellowish-tan shale beds with a few irregular sandstone members. Beds of brown carbonaceous shale and coal are numerous within the sandy shale, but none of the coal beds is thick enough to be mined.

The beds lying above the Claggett(?) formation and below the unconformity that separates the Montana group from the Fort Union are undifferentiated in this area because of insufficient paleontologic evidence. The fossils show that the beds are of Montana age, but they are not distinctive of either the Judith River or the Bearpaw formation. On lithologic grounds the rocks are divided into a lower, a middle, and an upper member. The lower division consists of gray cross-bedded sandstone, containing thin, irregular layers of flat and mud-ball conglomerate with macerated plant fragments and mineral charcoal. East of Bighorn River and about Tensleep Butte this member is eroded into prominent gray cliffs, and between Buffalo Creek and Bud Kimball Draw small areas of toadstool forms mark its line of outcrop. This member contains only small amounts of carbonaceous matter and no coal.

The middle division of the undifferentiated Montana is formed of beds of rusty-colored shale with here and there a layer of ferruginous sandstone. It diminishes in thickness from 90 feet at the north to less than 40 feet at the south. It is uniform in character from top to bottom, and contains no coal beds. No fossils were found except a few casts of small worm burrows.

The upper division of the undifferentiated Montana is composed of beds of ash-colored, tan, and drab sandy shale and brown carbonaceous shale with beds of coal. These beds range in thickness from a few inches to several feet. When freshly eroded the member is easily recognized by the somber-colored banded exposure. On account of an erosional unconformity above, the thickness varies greatly. Fossil leaves found in various localities indicate that the beds are of fresh-water origin and possibly of Judith River age. Beds of coal are found in the member wherever it is exposed, and beds of workable thickness occur in the valley of No Water Creek on both sides of the channel. A section of one of these beds (No. 7[a]) where it has been mined on No Water Creek shows 4 feet 11 inches of good coal, above which there is 7 inches of drab shale, then 6 inches of coal. Other beds almost thick enough to mine are exposed along Sandy Creek and between Buffalo Creek and Bud Kimball Draw, east of the "Honeycombs."

The Fort Union formation comprises two members, which can be distinguished more or less clearly throughout the field. The lower one consists of yellowish sandy shale and rusty sandstone resting unconformably upon the undifferentiated Montana. These beds weather so uniformly to yellow that in the field they were termed "yellow beds." The member is about 775 feet thick where it is crossed by the Worland-Tensleep road, and 2,300 feet near Bighorn River east of Kirby. These two measurements represent about the average limit of variation. This part of the Fort Union contains coal at the head of Bud Kimball Draw, where a mine has been opened on a lenticular bed 5 feet 6 inches thick at its maximum (No. 4), and also at the head of Cottonwood Creek (No. 3), where a little mining has been done. Some coal has also been mined from a small outlier northwest of Cedar Ridge (No. 6).

The upper member of the Fort Union in the northern part of the field is composed of gray and grayish-drab sandy shales and many thin lenses of yellow sandstone. To the south, however, the sandstone members become more numerous, massive, and yellow, but are still darker than the yellow beds below. This member contains no coal beds. Where crossed by the Worland-Tensleep road it is 225 feet thick; east of Kirby it is 600 feet thick.

The Fort Union as a whole contains an abundance of leaves, from which its age has been determined. It is composed of beds rapidly deposited under climatic conditions unfavorable to the accumulation of vegetable matter and consequently contains little coal. The formation is separated from the Wasatch above by an unconformity which is not clearly displayed in most localities but is sufficiently well shown at a few points to establish the break with certainty.

The Wasatch formation consists of sandy shale, mostly tan-colored, with some yellow, brick-red, and maroon beds. The bright colors give a banded appearance to the freshly eroded surface and where the rocks are weathered impart a pinkish cast to the detritus. The formation is exposed along the western and northern margins of the field, and in the great badland area to the west in the central part of the Bighorn Basin. The Wasatch contains no coal in this field.

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[a] Numbers in parentheses refer to locations on Plate XII.

Its age is fixed by vertebrate fossils found elsewhere in the Bighorn Basin by previous workers.

STRUCTURE.

The area here considered lies on the edge of a broad, moderately depressed structural basin. The beds have a general dip to the west-northwest, north, or northeast, varying from 3° to 56°, modified in only a few localities by minor folds or faults. From north to south the minor structural features may be described as follows: Between the north line of the field and the Worland-Tensleep wagon road the beds dip between 3° and 32° a little south of west. To the southeast, about Tensleep Butte, the dip is less and the strike changes more to the south. Northeast of this butte a small fault cuts the lower beds. The direction of this and other faults in the field is shown on the map (Pl. XII). Farther south, in the vicinity of the "Honeycombs," the rocks have a gentle dip, but to the east of that locality they are broken by a small fault. In the southern part of T. 45 N., R. 89 W., the beds are moderately folded, the strike turns sharply to the west, and the dip increases to 56° in sec. 35, T. 45 N., R. 90 W., but toward Bighorn River the dip again decreases to 10°. Near the river the beds are broken by several small faults. Wherever the coal beds are exposed in the area, however, the structure is not unfavorable to coal mining.

THE COAL.

OCCURRENCE AND DEVELOPMENT.

This field contains coal beds of workable thickness in four separate districts—near the head of Cottonwood Creek, on Bud Kimball Draw, along No Water Creek, and north of Kirby Creek, near Bighorn River. Beds of considerable thickness, but too thin to mine, outcrop along Sand Creek, between Bud Kimball Draw and Buffalo Creek, along No Water Creek, and in the region between Kirby and No Water creeks. Beds of coal are widely distributed throughout the area, but their location is not given on the map, because they are too thin and of too small extent to be commercially valuable now. The outcrop of the beds of coal and sections measured at various places along the exposures are shown on the map (Pl. XII).

It has been stated previously that one object of the survey was to determine the relation of the coal beds to land lines. This object could not be successfully accomplished because no reliable corner stones or posts were found, except along No Wood Creek and in the southwestern part of the area, near Bighorn River. The land lines could, therefore, not be established in the field, and the lines shown on the map are only suggestive and are not supposed to show the exact position the lines will occupy when they are resurveyed. Locations in the greater part of the area were found by a system of triangulation that established with a fair degree of accuracy the position of the coal beds in relation to hills, streams, and other landmarks.

Beds of coal thick enough to be mined occur in the Eagle (?) sandstone, the upper member of the undifferentiated Montana, and the lower member of the Fort Union formation. In adjoining areas, notably in sec. 29, T. 48 N., R. 89 W., a coal bed occurs in rocks which are geologically older than any that outcrop in this area and to which Darton[a] has given the name Cloverly formation.

It is generally supposed that the coal in the older geologic formations is of better quality than the coals deposited later. In this field only a few hundred feet of strata separate the lowest and highest beds and all have been influenced by the same structural movements. If there is a difference between the lower and higher coals due to geologic conditions it has not been detected by field study; however, the analyses given in the table (p. 183) seem to show that the coal in the lower beds is slightly better than that in the upper beds.

The mines of this field are small; in fact, none of them are more than prospects, though at several places a few tons of coal have been mined annually for a number of years. To begin at the north end of the field, the first coal bed which has been prospected is on Sand Creek, in the NW. ¼ NE. ¼ sec. 10, T. 49 N., R. 92 W., in the undifferentiated Montana. At this locality there is a prospect 100 feet deep on a bed which dips 18°. A section of the coal bed measured at a point 25 feet down the slope from the mouth is shown by section No. 1 on Plate XII. An examination along the entry and the outcrop of the bed shows that it is very lenticular and contains a large amount of shale and sandstone. The coal is subbituminous.

The next opening to the southeast has been made on a bed of coal in sec. 8, T. 48 N., R. 91 W., also in undifferentiated Montana rocks. The location of this prospect and a section of the bed at that point are shown on the map (No. 2). The dip of the beds here is 27° SW. The prospect in which the section was measured was driven about 75 feet and abandoned. It was found by following along the outcrop that this bed of coal disappears beneath surface cover a short distance to the north, but where last seen it is thinner than at the prospect. In the opposite direction from the opening there is only 14 inches of coal in an exposure one-fourth of a mile south, and in sec. 17 only a few inches of coal occur at this horizon.

Farther south along Sand Creek thin beds of coal outcrop at a number of points. The thickest bed in this group is exposed on the east side of Sand Creek, about 3 miles northwest of the Worland-

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[a] Darton, N. H., The geology of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51, 1906, p. 50.

Tensleep wagon road. The coal at this place is in two benches, the thicker of which contains 1 foot 8 inches of good coal capped by 6 inches of carbonaceous shale. A bed of coal about 2 feet thick is exposed about 1 mile farther southeast along the outcrop.

The only mine in the northern part of the field which is operated, even at intervals, is located on the east side of Cottonwood Creek, about 1¼ miles south of the crossing of the Worland-Tensleep road. The opening is at least 50 feet deep and widens out irregularly, but the extent of the development could not be determined because of the quantity of water in the mine at the time of examination. A section measured near the entry is shown by No. 3 on the map (Pl. XII). The bed is a lens in the lower part of the Fort Union formation. Valley wash covers the outcrop a short distance west of the mine and the bed is only a few inches thick one-fourth of a mile to the east. Some coal from this mine has been burned by ranchmen in the valley of No Wood Creek and plans have been made for its further development.

The most important mine in the area south of Tensleep Butte is in the badlands at the head of the north fork of Bud Kimball Draw, in sec. 33, T. 46 N., R. 89 W. More coal has been taken from this mine than from any other in the southeastern part of the Bighorn Basin. A section of the bed at the mine is shown by No. 4 on the map. The mine consists of an irregularly widened entry about 75 feet deep. Owing to its mode of weathering, the coal is classed as subbituminous. It has a pitchy luster, medium hardness, and subcubical jointing or cleavage. It contains small nodules of amber-colored resin and thin bands of mineral charcoal. It is probably a noncoking coal and does not stock well. The chemical properties of the coal are shown by analysis 6709, on page 183. The coal is in the Fort Union formation, and, like most of the beds in the field, is lenticular. One-fourth of a mile to the northeast the bed contains only 6 inches of coal, and an equal distance along the strike to the southeast an exposure shows an 8-inch bed included in carbonaceous shale. Although there is sufficient coal in the bed to furnish considerable fuel for local consumption, development has been prevented by the distance to settlements and the difficulty of maintaining wagon roads for transportation.

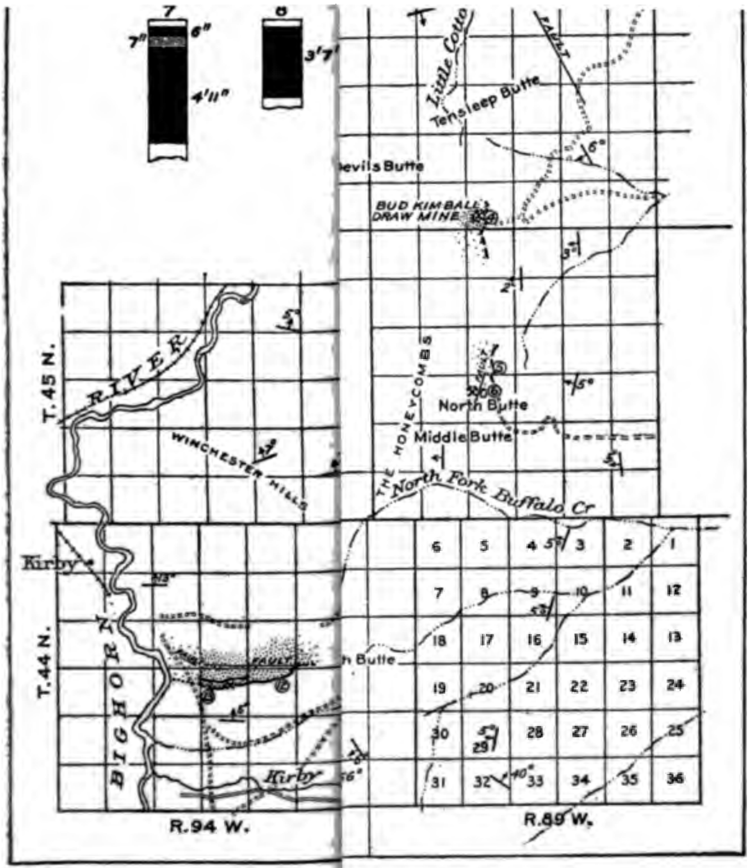
About 3½ miles south of the mine on Bud Kimball Draw there is an exposure of a coal bed at the base of a small isolated hill northwest of North Butte. The body of coal at this place is about 1 acre in extent and forms an outlier of a lens which originally was thinner toward the northwest, but now a dry coulée cuts the west side of this outlier. Where the bed is exposed across the coulée, it contains only 18 inches of coal at the thickest place. A section of the coal bed, shown by No. 6 on the map (Pl. XII), was measured in an open-pit mine on the west side of the hill, where the most favorable conditions for working the coal are found. The small extent of the bed at this place and its thin cover make it impossible for this mine to be more than a small country bank. A few tons of coal have been mined at this place by ranchmen and hauled over the divide road to the valley of No Wood Creek for fuel, but the coal is so dirty and the distance so great that the effort is scarcely repaid.

There are several coal beds in the upper member of the undifferentiated Montana where it is exposed east and northeast of the "Honeycombs," in T. 45 N., R. 89 W. Section No. 5 was measured a short distance north of the wagon road leading from the mine northwest of North Butte to No Wood Creek. The coal is subbituminous and occurs as a lenticular deposit. An entry driven into the bed in any direction may show an increasing or a decreasing thickness of coal, depending on whether the entry is driven toward the center of the lens or toward its margin. The locality is not favorable for mining.

A lower formation (the Cloverly of Darton), which is exposed to the east and dips under this field, contains a bed of coal where it is exposed in the valley of No Wood Creek, on the ranch of Dr. G. H. Walker, in sec. 29, T. 48 N., R. 89 W. The coal occurs as a lens, which extends for less than one-eighth of a mile along the outcrop. When examined in July, 1908, the mine was filled with water and an examination of the unweathered coal was impossible. At the mouth of the mine there is 2 feet of coal in a thick bed of carbonaceous shale. The bed is reported to be much thicker below the surface and this is probably true, because of the lenticular nature of the bed and the cross-bedded condition of the rocks above it. An opening was first made in this bed twelve years ago, and since then coal has been mined periodically. Mr. Diehl, who owns the property jointly with Doctor Walker, estimates that 2,000 tons have been taken out. The owners expect to reopen the mine and produce coal for the local ranch trade. The Cloverly formation does not outcrop in the area covered by this map, and in adjoining areas cursory observation and the reconnaissance by C. A. Fisher show that it contains only a small amount of coal.

The southern part of the field from the head of No Water Creek to Bighorn River contains more coal than the northern part, but owing to the lack of water and the entire absence of settlers there has been little development. Sections of coal beds measured at various points in the No Water area are shown on the map.

The only mine which has been opened in the No Water district is about 1 mile northwest of the creek, near the wagon road, about 3 miles southwest of South Butte. A section of the bed is shown by No. 7 on the map. The beds dip 23° N. The mine consists of an entry about 100 feet long with no side entries or rooms. The coal


7
7"
6"
4'11"
8
3'7"
Little Cotto
FAULT
Tensleep Butte
6°
evils Butte
BUD KIMBALL'S DRAW MINE
3°
2°
T. 45 N.
RIVER
5°
THE HONEYCOMBS
North Butte
5°
Middle Butte
5°
WINCHESTER HILLS
North Fork Buffalo Cr
Kirby
T. 44 N.
BIGHORN
FAULT
h Butte
Kirby
56°
R.94 W.
R.89 W.
6
5
4
3
2
1
7
8
9
10
11
12
18
17
16
15
14
13
19
20
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35
36
40°

seems to be subbituminous and of excellent grade. It is pitch-black with a vitreous luster, has a conchoidal fracture, and appears to slack slowly on exposure. A sample of the coal from this opening was analyzed with the result shown by No. 6708 in the table on page 183. About 150 tons of coal have been mined and the conditions at the mine are favorable for more extensive development, but its isolation in an uninhabited region which can be reached only over poor roads will probably prevent extensive working for some time to come. Along the strike to the east the bed is concealed for more than a mile, but where it reappears the dip is steeper and the coal bed is considerably thinner. West of the mine the coal bed dips less steeply and is more favorably situated for mining.

Coal is found on the east side of Bighorn River in the same formation that contains the beds mined at Gebo and Crosby, west of the river. The dip of the beds in this area is only 10°, which is less than it is farther west. Two coal beds separated by 22 feet of sandstone and shale are exposed in the low hills north of the valley of Kirby Creek, east of Bighorn River. These beds have been prospected at a number of places with very promising results and some coal has been mined for local markets. It is probable that the cheaper production of coal by the large companies west of the river has prevented further development, because they supply the only market open to the area that lies east of the river. The coal is of the same quality as that west of the river, but probably the beds are not so thick. The region is traversed by small coulées, along which roads can be constructed easily and railroad grades leading to mines would be moderate. There is no doubt that as the coal beds west of the river become exhausted the coal to the east will be developed.

CHARACTER OF THE COAL.

The coal of this field has the same general physical properties as that from other fields in the Bighorn Basin at corresponding geologic horizons. It is of pitch-black color, vitreous luster, cubical jointing or cleavage, and moderate hardness, and shows a dark-brown powder or streak on glazed paper. Small nodules of amber-colored resin are abundant. Sulphide of iron forms little flat disks along the joint planes, but seems to be absent in the body of the blocks. Minute seams parallel to the bedding planes are more highly bituminous than the body of the coal and when broken produce thin but highly vitreous and shiny bands. The coal appears to stock well, but from samples exposed at the mines it is thought that this property is apparent rather than real. It is probably explained by the dryness of the mines and is due to the condition which arises when dry coal is exposed. Very little moisture finds ready escape, the coal does not shrink much or unequally, and the blocks do not fall to pieces as soon as wet blocks of coal, which lose moisture rapidly.

The coal weathers on dumps to brown, slightly fissile, irregular grains, but where longer exposed to slower weathering becomes a fine brown powder resembling carbonaceous shale. So close is this resemblance that it is difficult to determine on surface exposures the line of separation between the coal bed and the associated carbonaceous shale. Fragments no larger than half an inch in diameter, though weathered outside, generally contain less altered material within, which shows some of the properties of the unweathered coal in the bed.

There were only two places in this field at which samples for chemical analyses could be taken, where the coal had been exposed recently below the zone of weathering. These two points were the mines on Bud Kimball Draw and on No Water Creek. Samples were taken at these mines by selecting a representative face of coal, freeing it from powder stain and surface impurities, and cutting a channel across the face about 1 foot wide and deep enough to yield 5 pounds of coal per foot of thickness of bed. From this cutting partings and binders more than three-eighths of an inch thick were rejected. The sample was then broken to pass a ½-inch mesh sieve and then repeatedly quartered, the opposite quarters being rejected until a small representative sample was obtained. A galvanized-iron can holding about a quart was filled from this sample, sealed with adhesive tape, and forwarded to the chemical laboratory for analysis. The table below shows the result of analyses of coal samples from this field and from the Gebo field west of Bighorn River.

Analyses of coal samples from the southeastern part of the Bighorn Basin coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B.t.u.
6708	19	44	90	5' 5"	5' 5"	18.3	As received	25.4	38.6	27.8	8.2	0.38					4,573	8,231
							Air dried	8.7	47.3	34.0	10.0	.46					5,597	10,075
							Dry coal		51.8	37.3	10.9	.51					6,132	11,038
							Pure coal[a]		58.1	41.9		.57					6,884	12,391
6709	33	46	89	5' 8"	5' 8"	8.20	As received	16.3	35.8	32.6	15.27	.96	5.63	50.84	0.71	26.59	4,921	8,858
							Air dried	8.8	39.0	35.6	16.63	1.05	5.14	55.38	.77	21.03	5,361	9,650
							Dry coal		42.8	39.0	18.24	1.15	4.56	60.74	.85	14.46	5,879	10,582
							Pure coal		52.3	47.7		1.41	5.58	74.29	1.04	17.68	7,191	12,944
6707	18	44	94	7' 6"	7' 6"	9.90	As received	16.9	34.1	44.0	5.01	.54	6.06	60.56	1.35	26.48	5,855	10,539
							Air dried	7.7	37.8	48.9	5.56	.60	5.51	67.21	1.50	19.62	6,498	11,696
							Dry coal		41.0	53.0	6.03	.65	5.04	72.84	1.62	13.82	7,042	12,676
							Pure coal		43.6	56.4		.69	5.36	77.52	1.72	14.71	7,494	13,489

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

6708. The coal for this analysis was dug at the bottom of a slope about 100 feet long, at a point where the cover is nearly 75 feet thick. The face had been exposed to the dry air of the region for several months previous to sampling. This condition probably has produced oxidation and a lower moisture content than will be found where the mine is extended to a depth of several hundred feet.

6709. This sample was taken in a dry unoperated mine 75 feet from the mouth of the entry and under about 50 feet of cover. Though the face from which the sample was taken had been exposed for several months, there was no evidence of weathering, but probably some change had taken place due to the action either of water percolating from above or of dry air absorbing some of the moisture. The coal was dry and the mine dusty; consequently, the analysis probably shows the result of oxidation and less moisture than will be found when the mine is extended deeper.

6707. The mine from which this sample was taken is not located in the field described in this report, but is 2 miles farther west across Bighorn River. This analysis is introduced because the sample is believed to be fairly representative of the unweathered coal in the Eagle (?) sandstone. The sample was taken at a point 615 feet down the slope from the main entry, where mining was progressing at that time at a depth of about 150 feet below the surface, and the coal seemed to be entirely unweathered.

The coal burns with a yellow flame and only a small amount of smoke. The ash is fine and does not clinker badly.

The coal is best adapted for domestic use, though with proper grates and drafts it can be used for steaming purposes. It is too light and slacks too readily to give the highest efficiency under forced draft, because in such fire boxes small particles of the coal are blown from the fires before they have a chance to burn.

In stoves the coal burns freely with a quick heat and little smoke and does not clinker. It slacks readily but may be kept in small quantities for a long time; so that this property is not objectionable at present, because the local ranch men usually mine only a few tons at a time.

AMOUNT OF COAL AVAILABLE.

It is difficult to estimate the amount of coal in this field, owing to the uncertainty which the occurrence in lenticular beds gives to such computation. Any estimate may be as much as 25 per cent too small or too large. The northern part of the field contains a little coal in very irregular lenses. As the badlands to the west of the Cottonwood Creek and Bud Kimball Draw districts form a barrier to any market except that of the ranchers along the valley of No Wood Creek, it may be stated that in this part of the field there is coal to furnish sufficient fuel for many years if the mines are properly laid out and maintained, but the present unscientific, wasteful methods will greatly shorten the period of profitable production. The southern part of the field contains more coal than the northern part. It is estimated, on the assumption that the coal has a specific gravity of 1.3, that there are 62,000,000 tons of coal in this region in beds more than 3 feet thick and less than 2,000 feet deep. It is impossible to mine more than 75 per cent of this amount by present mining methods; hence not more than 46,500,000 tons are available as a future source of supply.

MARKET.

It has been stated that market conditions are unfavorable except for a small area in the extreme southwestern part of the field. The coal must be hauled by wagon at least 10 miles over rough roads and much of it a considerably greater distance. The demand is for fuel on ranches, as no towns are near enough to afford a market. The coal to the southwest near Bighorn River is within a few miles of a railroad, where it can be marketed now by hauling a short distance by team. It can be reached by a short railroad spur when the coal is in sufficient demand. The only competing fuel in the field is wood, which is not abundant.

FUTURE DEVELOPMENT.

It is expected that the area of coal near Bighorn River east of Kirby will receive attention from miners as soon as the coal to the west becomes a little more difficult to obtain. Elsewhere in the field the conditions are not promising for future development beyond the mining of a few tons each year by local ranch men who can overcome the difficulties of haulage. Further, owing to poor land surveys the coal areas can not be segregated and valued; hence title to them can not be obtained from the Government until a resurvey is made. These conditions will delay development.

THE EASTERN PART OF THE LITTLE SNAKE RIVER COAL FIELD, WYOMING.

By Max W. Ball and Eugene Stebinger.

INTRODUCTION.

The Little Snake River coal field includes an area of about 1,150 square miles, approximately 900 square miles of which is in Carbon and Sweetwater counties, Wyo., and 250 square miles in Routt County, Colo. It is separated from the Yampa field on the south by the crest of the Elkhead Mountains, and from the Great Divide Basin field on the north by the watershed between the Pacific drainage and that of the Great Divide Basin. It was first mapped geologically by the King Survey in 1871–72. In 1902 the part of the field lying generally north of Little Snake River and east of Battle Mountain was included in Spencer's map of the Encampment copper district.[a] The Wyoming portion of the field has been the subject of two seasons' field work with especial reference to coal. During the summer of 1907 a party consisting of Max W. Ball, B. L. Johnson, J. T. Singewald, jr., L. Reinecke, Robert D. Sawin, and Ray D. Sawin surveyed the area north of Little Snake River and west of a line passing through Dixon, Five Buttes, and Bridger Pass, including that portion of the Great Divide Basin which lies south of the Union Pacific Railroad. In the season of 1908 a party comprising Max W. Ball, Eugene Stebinger, C. L. Baker, and Arthur M. Douglass completed the mapping of the Wyoming part of the field, as well as of a few small areas in Colorado north of Little Snake River, and in addition made a further study of some of the area examined during the previous season. This paper is a brief report of the results of the investigations of 1908 and of necessity duplicates or revises, both in map and text, many of the statements presented in the preliminary paper on the western part of the field.[b]

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[a] Spencer, A. C., Copper deposits of the Encampment district, Wyoming: Prof. Paper U. S. Geol. Survey No. 25, 1904.

[b] Ball, M. W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 243-255.

The mapping in the field was done on a scale of 2 inches to the mile, with contour intervals of 100 feet. A few small areas were sketched by plane-table methods, but the greater part of the work was done by pacing land lines on horseback from section corner to section corner, each corner found being used as a new and correct location for continued work. The horizontal control of the map thus depends largely on the presence of land corners, and the location of features with respect to land lines is accurate in proportion to the number of monuments found. North of the fourth standard parallel north corners are rather numerous and easily discovered; south of that line they are relatively scarce. E. Lambert, as county surveyor, established corner stones in most of T. 16 N., R. 92 W., and in portions of T. 15 N., Rs. 91 and 92 W. From the township corner just southeast of Five Buttes a line of original corners extends 3 miles west; another runs possibly 3 miles south; about one-third of the original corner stones are present for 6 miles on the line north; and a line of unmarked stones continues 3 miles east. A number of corner stones were found in T. 12 N., Rs. 89, 90, and 91 W., and T. 13 N., Rs. 90 and 91 W., and a very few in T. 14 N., R. 89 W.

In the summer of 1907 a line of levels was run diagonally across the field from a United States Coast and Geodetic Survey bench mark at Rawlins, on the Union Pacific Railroad, to Baggs, bench marks being set about every 3 miles from Rawlins to Muddy Bridge and two between Muddy Bridge and Baggs. From these bench marks and from those in the area east of Battle Mountain established during the topographic survey of the Encampment special quadrangle in 1901, flying levels were carried by telescopic alidade and stadia to the various temporary camps of the party, furnishing control for the aneroid and hand-level altitudes used in sketching.

From the field sheets a complete contour map on a scale of 1 inch to the mile was compiled in which the lengths of the land lines as given by the official Land Office surveys were accepted as correct and were plotted by so balancing the recorded distances about a vertical and a horizontal right line intersecting near the southeast corner of T. 16 N., R. 91 W., that the distortions due to convergence of meridians and errors of survey are theoretically distributed equally over the sheet. As a result of this balanced plotting of the recorded lengths of land lines rather than their bearings, the length of the sides of any particular township or section is the same as that given on the corresponding Land Office plat, but the shape of the township or section may be different from the shape shown on that plat. From the contour map, by reducing the scale and eliminating everything but the more important drainage and cultural features, the base was prepared for the accompanying map (Pl. XIII), on which are indicated the different geologic formations in the coal area, the locations of the principal coal openings, and such other geologic facts as have a direct bearing on the occurrence or development of the coal. No attempt is made to show the subdivisions of the geologic column except in the coal-bearing part.

There are represented in the field and its vicinity sedimentary rocks down to the "Red Beds" of the Triassic, but neither the formations below the Mesaverde nor the igneous rocks upon which the "Red Beds" rest unconformably are indicated on the map. All the beds above the "Upper Laramie," including the Wasatch and later Tertiary formations and part of the alluvial deposits are shown by a single pattern.

Acknowledgment is due to a large number of persons in the field who in person and by correspondence have facilitated the work through information given and courtesies extended.

SURFACE FEATURES.

The Little Snake River coal field presents every topographic gradation from the heavily timbered slopes of the Elkhead Mountains and Sierra Madre to the alkali flats of the Red Desert. Little Snake River, in the drainage basin of which the field lies and from which it takes its name, originates in the confluence of three tributary streams a short distance east of the coal field and crosses it in a course trending almost directly west through a fertile flat-bottomed valley from half a mile to 2 miles wide, flanked here and there by benches or mesas which increase in number toward the western margin of the field. Immediately north of the river in the eastern part of the field the lava-capped eminences of Sheep Mountain, Mule Mountain, Horse Mountains, and, highest and most prominent, Battle Mountain, overlook abruptly a great plateau extending eastward to the base of the Sierra Madre and northwestward to Browns Hill and Five Buttes. In this comparatively level upland Savery and Battle creeks and their tributaries have cut precipitous canyons, whose bottoms in many places are rich agricultural land. The regularity of this upland is interrupted in the vicinity of Browns Canyon and Rubey Springs by a higher mesa, with white escarpment faces. North of this higher mesa, toward Sulphur and Bridger Pass, the upland loses most of its plateau characteristics and becomes a series of high ridges with cliffs toward the east and dip slopes toward the west. Muddy Creek crosses this highland in a deep, narrow canyon known as the Upper Narrows of the Muddy, and its headwaters have hollowed out a valley called Muddy Basin between the eastward-facing cliffs and the higher mesa that extends northward and eastward from Rubey Springs. West of the plateau is a depression, in places a simple valley, elsewhere a broad area of low, irregular relief, terminated on the west by a series of hogbacks and transverse ridges, with a few high points such as Muddy Mountain. In the area described in this paper the western limit of the hogback region is marked by a brilliantly colored escarpment, which constitutes approximately the western margin of the coal field and the eastern border of a great, almost waterless area of badlands, broken dip slopes, and isolated buttes locally known as "the desert." Along the face of this scarp from the old Washakie stage station southward Muddy Creek meanders through a flat-bottomed valley to its junction with Little Snake River at Baggs.

GEOLOGY.

STRUCTURE.

The geologic structure of this area is dominated by the uplift of the Sierra Madre just east of the field. The attitude of the coal-bearing formations varies from horizontality to a dip of 35°, the dip being generally greatest near the western margin of the area. The direction of dip is slightly west of north in the north end of the field and swings through due west to southwest in the vicinity of Little Snake River. Along this river above Savery Creek there are many minor folds which produce dips of as much as 4° in every direction and give to the outcrop of the lowest coal-bearing formation, the Mesaverde, a width of approximately 15 miles, as compared with 3 miles, both in the vicinity of Bridger Pass, near the north end of this field, and at Wolf Mountain, in the Yampa field.[a] The dips of the beds overlying the coal-bearing formations are uniformly low. The Wasatch dips generally from 1° to 4° W., although in places it has a higher dip immediately in contact with the older beds; the Bishop (?) conglomerate (Tertiary) is either horizontal or dips 1° or 2° E.

Only one fault of any magnitude was observed in the field. This crosses the river in sec. 16, Wyoming, and sec. 17, Colorado, T. 12 N., R. 88 W. Its throw could not be ascertained, but probably is not less than 50 feet. The location is within a mile and a quarter of the highest point on Battle Mountain, which is probably, like its neighbor, Sheep Mountain, the site of the vent whence issued the basalt now forming its cap.

STRATIGRAPHY.

GENERAL SECTION.

A section of the rocks of the field from the Sierra Madre westward would give an incomplete succession of the formations from the pre-Cambrian upward. In the following table the general character and approximate thicknesses are given for only the coal-bearing and associated formations:

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[a] Fenneman, N. M., and Gale H. S., The Yampa coal field, Routt County, Colo.: Bull U. S. Geol. Survey No. 297, 1906.

Generalized section of coal-bearing and associated rocks in the southern part of the Little Snake River coal field, Wyoming.

System.		Formation.	Thickness (feet).	Characteristics.	Coal resources.
Tertiary.		Bishop (?) conglomerate.	1,000±	White to light-gray calcareous sandstone and sandy limestone north of Bird Gulch; yellow to white beds of poorly consolidated sand and gravel in south end of field. Basal conglomerate.	Not coal bearing.
		Unconformity			
	Eocene series.	Wasatch formation.	Top not seen.	Variegated clay, passing upward into brown and gray shales, sand, and sandstone. Highly calcareous conglomerate at base in some parts of field.	Not coal bearing.
		Unconformity			
		"Upper Laramie" formation.	0 to 4,000.	Gray and brown sandstones and gray and drab shales, with many coal beds. White to dark clay shale. Heavy sandstone, with interbedded shale and numerous beds of good coal; conglomerate at base.	Coal bearing throughout except in white to dark clay shale member. Bottom part contains best coal beds.
Cretaceous.		"Laramie" formation.	3,500.	Brown and gray shaly and concretionary sandstones and dark shale, with several beds of coal. In parts of the field the lower half is yellow, softer, and more sandy, and apparently contains less coal than the upper half.	Contains some coal.
	Montana group.	Lewis shale.	1,600.	Drab, slightly sandy, highly gypsiferous shale, with a few beds of thin soft sandstone.	Not coal bearing.
		Mesaverde formation.	2,000.	Upper two-thirds alternating sandstone and shale beds, with heavier sandstone beds in upper part. Bottom third made up of massive cross-bedded sandstone with some interbedded shale.	Upper two-thirds contains many coal beds and principal mines in the field. Bottom third not coal bearing.
				Dark-drab concretionary calcareous shale, with several thin beds of soft brown sandstone.	Not coal bearing.

MONTANA GROUP.

SHALE.

Immediately underlying the lowest coal-bearing formation in this field is a non coal-bearing shale, the equivalent of the upper part of the Mancos shale as mapped and described in western Colorado. It has a thickness of not less than 2,000 feet, is dark drab in color, weathers almost white in places, is somewhat concretionary and very calcareous, and contains numerous thin beds of soft brown sandstone, especially near the top. A particularly persistent sandstone, which has been observed throughout this field, the Great Divide Basin, and the east-central Carbon County field, occurs about 200 feet below the base of the Mesaverde, and as the dips are high or low forms either a hogback or a secondary scarp a short distance out from the foot of the Mesaverde escarpment.

MESAVERDE FORMATION.

The Mesaverde formation may be divided readily, though not definitely, into three practically equal parts. The lower third is made up of massive white, gray, and rusty-brown cross-bedded sandstone, with some interbedded shale and shaly sandstone. North of the Upper Narrows of the Muddy a bed of limestone 25 feet thick was observed about 150 feet above the base of the formation. The line of demarcation between this lower member, which is not coal bearing, and the underlying shale is not everywhere distinct. Near Standard Headquarters on Savery Creek the transition is marked for 300 feet or more by an alternation of beds of heavy sandstone 2 to 50 feet thick, with beds of drab, white-weathering shale 1 to 30 feet thick. The upper two-thirds of the formation is composed of alternating thin-bedded and shaly sandstones, gray, brown, and drab shales, and a few beds of massive sandstone that increase in number toward the top of the formation, so that where the beds are tilted the upper and lower members of the formation stand out as high ridges and the middle member occupies a depression between. In the southeastern part of the area shown on the accompanying map (Pl. XIII), where the beds are nearly flat and are covered by the Bishop (?) conglomerate, the Mesaverde produces a great plateau with deep canyons. The middle member is coal bearing in the south end of the field, containing the Carbondale (1),[a] Stemp Springs (2), and probably the Linde (3) and Lucksinger (4) mines. Toward the north the coal beds become less numerous, thinner, and dirtier. In a section across the formation at the Upper Narrows of the Muddy no coal was found in the middle member, although the outcrop is covered in a few places and may contain coal beds. The upper member contains a number of coal beds throughout the field, the Robertson (16), Angier (7), Darling (6), Martin (5), O. P. Beeler (18), and possibly the Lucksinger and Linde openings being on coal beds in this member. The following section through the Upper Narrows of the Muddy just east of Sulphur shows the location, number, and thickness of the coal beds in the upper member in the northern part of the field:

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[a] Numbers refer to locations on Plate XIII.

Section of a part of the Mesaverde formation north of Muddy Creek in Tps. 17 and 18 N., R. 90 W., Wyoming.

	Thickness.	Distance from base of formation.
	Feet.	*Feet.*
Covered, shale, chocolate or drab, thin-bedded sandstone and coal, approximately	300	1,973
Sandstone, thin bedded, buff, somewhat reddened by heat, with small amount of shale	30	1,673
Sandstone, thin bedded	3	1,643
Shales, black, carbonaceous, and brick-red, giving evidence of a burned coal bed	12	1,640
Sandstone, thin bedded, buff, with thin streaks of buff shale	45	1,628
Shales, bituminous and drab	14	1,583
Coal (Robertson opening)	11	1,569
Shales, bituminous and chocolate drab	10	1,558
Sandstone, thin bedded, buff	44	1,548
Coal	1	1,504
Sandstone, thin bedded, buff	20	1,503
Shale, drab, with thin beds of coal	9	1,483
Coal, at least	7	1,474
Shale, chocolate or drab, with thin beds of coal	6	1,467
Sandstone, massive, buff	18	1,461
Shale, dark, with abundant plant remains and at least six beds of poor shaly coal less than 1 foot thick	15	1,443
Coal	5	1,428
Covered	15	1,423
Sandstone, thin bedded, buff	2	1,408
Shale, dark brown	5	1,406
Sandstone, massive, buff	15	1,401
Coal	10	1,386
Shale, black	5	1,376
Sandstone, massive, buff	35	1,371
	637	

Lack of continuous exposures makes it impossible to tell whether or not individual beds of Mesaverde coal extend continuously for long distances. Some of the prominent sandstone ledges of the lower part of the formation may be traced for many miles, but the sandstone beds of the coal-bearing members of the formation do not appear to be so persistent. It seems probable that the beds are more or less lenticular and that in general where one bed thins out and disappears another one is present, so that the number of beds remains about the same and the coal maintains an approximately constant aggregate thickness, but no one bed is continuous over a great area.

LEWIS SHALE.

The Lewis shale is soft, dark drab to black in color, and highly gypsiferous, with a few beds of soft shaly sandstone that increase in number toward the top of the formation. The sandstone varies in color from white to rusty brown, and the shale is slightly more sandy near the top of the formation than it is lower down. The shale weathers rapidly, producing between the highlands of the Mesaverde, on the one hand, and the less prominent "Laramie" hogbacks, on the other, an almost continuous valley, or series of valleys, of which advantage has been taken in locating a great part of the Rawlins-Baggs stage road (formerly the government road from the

Union Pacific Railroad to the White River Indian Agency), as well as a number of other roads. No coal was observed in the Lewis shale in this field.

"LARAMIE" FORMATION.

The "Laramie" formation is made up of interstratified beds of gray, buff, and rusty-brown sandstone, and gray, brown, drab, and black shale. The sandstone as a rule is thin bedded, but some beds are massive and a few are concretionary. In some parts of the area, notably along Cherokee Creek, there is a marked difference between the upper and lower parts of the formation, the sandstone in the lower half appearing more shaly and less consolidated and the shale zones more numerous and sandy than in the upper half. The result is a sandy shale member with a few beds of resistant sandstone about midway in character between the normal upper part of the formation and the underlying Lewis shale. In the northern part of the field the formation is uniform throughout, the base of the formation as mapped being a massive white sandstone,[a] which as a rule forms either an escarpment or a prominent hogback. At Muddy Mountain, south of Cherokee Creek, the lower half of the formation seems to be even more resistant than the upper, with a greater percentage of indurated sandstone.

The "Laramie" formation is undoubtedly coal bearing throughout the Wyoming portion of the field, but the number, thickness, and relative location of the coal beds could not be definitely determined in the area treated in this paper, owing to the prevalent cover of hill wash over the formation and the fact that most of the coal beds do not occur between beds of sandstone but in shale that weathers rapidly and hence produces a minimum of exposures. In the field no mines are located in the "Laramie" and only one prospect, that in the SW. ¼ NE. ¼ sec. 15, T. 12 N., R. 90 W. (No. 8), opposite the Deary ranch. Owing to the presence of valley filling, river terrace, and Tertiary deposits several miles in extent between this location and the nearest "Laramie" exposure to the north, the reference of even this coal bed to the "Laramie" is a matter of no great certainty.

"UPPER LARAMIE" FORMATION.

The lowest member of the "Upper Laramie" formation is composed of beds of gray and brown sandstone, with intercalated gray, brown, and drab shale and numerous beds of coal. The beds of sandstone are thicker, more numerous, and more massive toward the base, which is marked by a bed that is extremely massive, cross-bedded, in many places highly ferruginous, and as a rule somewhat conglomeratic. The pebbles are composed of well-rounded crystalline and cryptocrystalline materials, chert predominating, and as a rule they are small, but lenses of conglomerate with pebbles up to 18 inches in diameter appear locally. In the southern part of the field a basal conglomerate is present, in places in contact with or forming a part of the massive sandstone. In other places, notably just east of the Standard ranch on Muddy Creek, the basal conglomerate is represented by two beds, each about 8 feet thick, approximately 100 and 200 feet below the massive sandstone and separated from it and from one another by dark shale. The pebbles are mainly chert, held in a matrix of chert and crystalline quartz grains about the size of coarse sand.

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[a] This mapping is based on the fact that the formation from the bottom of this sandstone upward is a lithologic unit. Paleontologically the formation probably begins some 400 feet higher, as marine Montana fossils have been found to that distance above the massive sandstone, thus associating the lower 400 feet of the formation as mapped with the Lewis shale.

On the coal beds of the lowest member are the Muddy Bridge opening, the openings in Coal and Cutoff gulches, northeast of Baggs, and a number of other prospects. The individual coal beds appear to be continuous for long distances. An idea of the lithologic character, number, and position of the coal beds may be gained from the following section taken along the Lower Narrows of the Muddy near the old Washakie stage station. Farther south some of the beds are thicker than any shown in this section.

Section of a part of the "Upper Laramie" formation near old Washakie stage station. north of Muddy Creek, in Tps. 17 and 18 N., R. 91 W., Wyoming.

	Feet.
Shale, brown	70
Sandstone and burned coal bed, intensely red	20
Covered mainly; where exposed brown, black, and gray shale, with thin-bedded brown sandstone	80
Sandstone, massive and thin bedded, yellow	50
Shale, brown	8
Coal	5
Shales, sandy, yellowish and brown, with shaly sandstone	61
Shale, gypsiferous, brown, with thin coal beds	10
Sandstone, shaly and thin bedded, yellow and brown, with sandy shale	33
Shale, gypsiferous, brownish black	3
Coal	5
Shale, sandy, light gray	5
Sandstone, thin bedded, yellow	6
Coal, impure	7
Shale, brown	2
Shale, sandy, yellowish brown	4
Coal	2
Shale, gray	5
Shale, sandy and yellowish brown, shaly sandstone	10

Shale, bluish gray, with plant remains	4
Coal, burned in places	5
Covered; creamy sandstone near middle, brown shale at top	344
Sandstone, cross-bedded, conglomeratic, grayish and light brown	25
Sandstone, buff, conglomeratic. Small pebbles of diabase, chert, and crystalline quartz scattered sparingly throughout except near top, which is full of pebbles one-fourth inch to 18 inches in diameter, with evidences of local unconformity	80
	844

Overlying the lowest member of the "Upper Laramie" is a non coal-bearing member, consisting of clay shale and sandy clay, with a small amount of soft sandstone, either massive or thin bedded. In the northern portion of the field the clay is almost pure white, whereas in some of the exposures near the river it is dark drab, bordering on black, with rare tinges of red, which may have been leached from the adjacent Wasatch. The beds of sandstone in this member, which are extremely varied in number, thickness, and location, are as a rule gray. Throughout the greater part of the area the member appears to be free from conglomerate, but in many places between Cherokee Creek and Deep Gulch large quantities of rather coarse cherty conglomerate are present. Although this clay shale member is easily and definitely recognizable wherever exposed from the Union Pacific Railroad to its disappearance under the Wasatch just north of Little Snake River, its thickness seems to vary markedly through lithologic encroachment upon it of the underlying and overlying members.

The uppermost member of the "Upper Laramie" is composed of gray and brown sandstones with interbedded shale. Some of the shale beds closely resemble those of the clay shale member, from which the upper member is, however, distinguished by the greater number and superior resistance of its beds of sandstone and by the presence, where exposures are satisfactory, of numerous beds of coal. In the area specifically treated in this paper outcrops of this member are not numerous, owing to the overlapping of the Wasatch formation, which through most of the area covers it completely. The coal beds of the member have not been carefully prospected, although from Riner, on the Union Pacific Railroad, to Coalbank Spring,[a] the beds are very prominently exposed.

Regarding the geologic age and the equivalence of this formation there has been some uncertainty. It doubtless constitutes the earliest Tertiary deposit of the area, and from paleobotanical evidence F. H. Knowlton now considers it to be of Fort Union age. The formation as mapped is the equivalent of the "Upper Laramie" of Veatch[a] in the Hanna field, where it is separated from the "Laramie" ("Lower Laramie" of Veatch) by a great unconformity. This unconformity was also observed by Smith in the Great Divide Basin[b] north of the Union Pacific Railroad, but though evidence of local unconformity appears in one or two places, no general unconformity was observed in the Little Snake River field. In secs. 25 and 26, T. 13 N., R. 91 W., a few isolated exposures were found with strikes trending much more toward the east than any of the underlying formations, but the cover of Wasatch and later deposits southward to the state line made it impossible to determine whether these exposures represent a local fold or a definite trend of the formation which could only be accommodated by its unconformably overriding some of the older beds.

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[a] Ball, M. W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, Plate XIII.

WASATCH FORMATION.

The Wasatch is separated from the underlying formations by a pronounced unconformity. West of the old Washakie stage station the base of the formation rests on the upper member of the "Upper Laramie." South of the Standard ranch on Muddy Creek it rests on the lowest member of the "Upper Laramie." From this point south it oscillates between these two positions as far as the Dixon Cutoff, where it swings abruptly eastward and overlaps the formations down to the top of the Mesaverde. The Wasatch formation is composed mainly of rather sandy clay, with a few beds of shale and soft sandstone, the latter mostly massive and in places finely conglomeratic. Higher in the formation the proportion of clay to shale decreases, the beds of sandstone increase in number, and the sandstone is thin bedded and more resistant. The usual coloring of the clay, which is roughly bedded, is brilliantly banded red and white, although purple, green, drab, and yellow colors are common, and in places, notably along the north bank of Little Snake River just below Dixon and the south bank just above that point, the color is almost entirely leached out. Locally the shale partakes of the brilliant coloring of the clay but as a rule it is green, yellow, brown, and drab and the sandstone is gray and rusty brown. As the proportion of clay decreases toward the upper part of the formation the red color becomes less prominent, appearing here and there in a diminishing number of isolated patches, until the formation is almost entirely composed of white, gray, brown, and drab shales and clays, with a number of thin bedded gray and rusty brown sandstones. In some places it is difficult to distinguish at first glance between the uppermost part of the Wasatch and the "Laramie" or the upper member of the "Upper Laramie," but a careful search over any considerable area will almost invariably show one or more patches of bright red color. The lowest member of the formation in the region just south of Muddy Mountain seems to be a yellow or white conglomeratic sandstone, in places highly calcareous.

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[a] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 244 260.

[b] Smith, E. E., The Great Divide Basin coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 224, 233.

The Wasatch is very prominently exposed along Little Snake River for many miles below Baggs and south of the river in the lower slopes of Black Mountain.

BISHOP (?) CONGLOMERATE.

In his mapping of the geology of the Encampment district, Spencer,[a] following the usage of the King Survey, adopted the name "Wyoming" conglomerate for the sandstone conglomerate which caps the interstream areas in the southwestern part of the district that he examined, including that part of the Little Snake River field lying north of the river and east of a north-south line along the east base of Battle Mountain. It is probably the equivalent of the "Bishop Mountain" conglomerate of the Powell Survey, now called Bishop conglomerate. The basal conglomerate of the formation covers the greater part of the level upland from the vicinity of Bridger Pass to the river. It is 50 feet or more in thickness and obscurely bedded, with poorly assorted pebbles of all sizes up to bowlders 2 feet in diameter, and with lenses of white and yellow sandstone, rather soft and more or less massive.

Above the basal conglomerate on Sheep and Battle mountains and in the Elkhead Mountains south of the river lie several hundred feet of poorly consolidated sand and gravel. On the north slope of Battle Mountain some of the sand is of extreme fineness, whereas other beds are very pebbly, and on the north face of Black Mountain, south of Dixon, a great thickness of very coarse unconsolidated conglomerate is exposed. In the vicinity of Sheep and Mule mountains the beds are consolidated into a gray massive sandstone, highly cross-bedded, showing mud cracks in many places. On the north wall of Bird Gulch just above Savery Creek (sec. 26, T. 15 N., R. 89 W.) the basal conglomerate is well exposed, lying unconformably upon the westward-dipping sandstone of the Mesaverde formation and dipping slightly northward to Browns Canyon and Rubey Springs, where it apparently forms the base of a series of white sandy limestone and calcareous sandstone, the westward continuation of the formation which Veatch[b] mapped near Platte River and elsewhere as North Park. It thus seems highly probable that the Bishop (?) conglomerate is a phase of the North Park Tertiary, differences in lithology being produced by different sources of materials, closer proximity to those sources, and somewhat different conditions of deposition.

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[a] Spencer, A. C., Copper deposits of the Encampment district, Wyoming: Prof. Paper U. S. Geol. Survey No. 25, 1904.

[b] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, Plate XIV.

ERUPTIVE ROCKS.

Battle, Sheep, and Mule mountains and the Horse Mountains are covered with lava caps from a few feet to 300 feet and more in thickness. One vent from which the eruptive mass issued was located on Sheep Mountain. Probably Battle Mountain and possibly one of the Horse Mountains also were sites of openings.

LATER DEPOSITS.

Along the sides of Little Snake River valley are benches at different elevations, covered by gravel which either was deposited by the river at its former levels or represents remnants of alluvial slopes. The higher ones are difficult to distinguish from the apparent terraces formed by the lowest beds of the Bishop (?) conglomerate.

The river since reaching its present level has filled with alluvium the valley through which, with numerous riffles, it meanders. Its principal tributaries from the north, Battle, Savery, and Muddy creeks, also occupy aggraded valleys in their lower courses. This is especially noticeable in Muddy Creek, which flows through alluvium for nearly 40 miles, the last 25 miles being almost entirely through reworked clay of the Wasatch formation, which has not the fertility shown in the bottom land along Savery and Battle creeks.

In the vicinity of The Willows is a great area of dunes built up by sands brought from the desert by the prevailing southwest winds. These dunes are traveling toward the Upper Narrows of the Muddy and from present indications may in time partly fill that canyon. A second small sand-dune area exists south of the Standard ranch, on Muddy Creek.

Finally, over a great part of the field is spread a mantle of overwash derived mainly from the beds which it covers, with a sprinkling of igneous pebbles probably left from the erosion of some overlying conglomerate.

The areas covered by all these later deposits are only partly shown on Plate XIII.

THE COAL.

CHEMICAL PROPERTIES.

The prime object of the survey of this field was the classification and valuation of the coal lands. With this end in view samples of the freshest coal obtainable were taken, but it was impossible to get completely unweathered coal owing to the lack of adequate openings and fresh working faces. The samples are therefore not comparable to many of those obtained in the same formations by Veatch in the Hanna field[a] and by Schultz[b] in the Rock Springs field, where the samples were taken from fresh faces in large working mines.

The coal samples, which were taken according to the method described in Bulletin 341,[c] were analyzed at the Geological Survey fuel-testing plant at Pittsburg, Pa. In the table below are given the analyses of all samples taken in the portion of the field represented on the accompanying map, including some which were published in the report on the western part of the field.[d] In addition, to illustrate the character of the "Laramie" coal, of which it was not possible to procure an unweathered sample in the field, two previously published analyses of the coals of this formation in neighboring fields are given.

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[a] Veatch, A. C., Coal fields of east-central Carbon County, Wyo.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 253-258.

[b] Schultz, A. R., The northern part of the Rock Springs coal field, Sweetwater County, Wyo.: Bull. U. S. Geol. Survey No. 341, 1909, pp. 270-273. See also paper on the southern part of the Rock Springs field, pp. 104-171 of this volume.

[c] Campbell, M. R., Bull. U. S. Geol. Survey No. 341, 1909, p. 12.

[d] Ball, Max W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, p. 251.

Analyses of coal samples from the Little Snake River coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. N.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6642	SE. ¼ SW. ¼	7	13	87	2' 10''	2' 10''	7.9	As received	13.0	33.4	45.5	8.10	1.10	5.70	60.39	1.35	23.36	5,955	10,719
								Air dried	5.6	36.2	49.4	8.79	1.19	5.23	65.57	1.47	17.75	6,466	11,639
								Dry coal		38.4	52.3	9.31	1.26	4.89	69.43	1.55	13.56	6,846	12,323
								Pure coal [a]		42.3	57.7		1.39	5.39	76.56	1.71	14.95	7,549	13,588
6644	NE. ¼ SW. ¼	13	13	88	2' 10''	2' 10''	5.1	As received	10.8	36.0	46.3	6.94	2.25	5.78	62.77	1.40	20.86	6,232	11,218
								Air dried	6.0	37.9	48.8	7.31	2.37	5.49	66.14	1.48	17.21	6,567	11,821
								Dry coal		40.4	51.8	7.78	2.52	5.13	70.35	1.57	12.65	6,985	12,573
								Pure coal		43.8	56.2		2.73	5.56	76.29	1.70	13.72	7,575	13,635
6603	SE. ¼ SW. ¼	8	12	88	8'	8'	11.7	As received	16.1	29.0	38.6	16.26	.64	5.28	50.42	.88	26.52	4,933	8,880
								Air dried	5.0	32.9	43.7	18.42	.73	4.51	57.09	1.00	18.25	5,587	10,057
								Dry coal		34.6	46.0	19.38	.76	4.16	60.10	1.05	14.55	5,880	10,584
								Pure coal		42.9	57.1		.94	5.16	74.55	1.30	18.05	7,294	13,129
6643	SE. ¼ NE. ¼	18	12	88	12' 2''	6' 10'' lower portion of bed.	6.5	As received	13.0	35.7	45.0	6.34	.65	5.78	61.54	1.14	24.55	5,904	10,627
								Air dried	6.9	38.2	48.1	6.78	.70	5.41	65.82	1.22	20.07	6,314	11,365
								Dry coal		41.0	51.7	7.28	.75	4.99	70.70	1.31	14.97	6,783	12,209
								Pure coal		44.2	55.8		.81	5.38	76.25	1.41	16.15	7,315	13,167
5444	SW. ¼ NW. ¼	9	12	89	8'	Upper 7'	5.7	As received	15.8	33.3	47.5	3.44	.58	5.89	62.01	1.10	26.98	5,957	10,723
								Air dried	10.7	35.3	50.3	3.65	.62	5.58	65.76	1.17	23.22	6,317	11,371
								Dry coal		39.5	56.4	4.09	.69	4.90	73.64	1.31	15.37	7,075	12,735
								Pure coal		41.2	58.8		.72	5.11	76.78	1.37	16.02	7,377	13,278
5449	SW. ¼ SE. ¼	5	12	89	15' 6''	7' 6'' lower bench.	5.3	As received	14.4	31.8	48.7	5.11	.55	5.82	62.37	.89	25.26	5,997	10,795
								Air dried	9.6	33.6	51.4	5.40	.58	5.52	65.86	.94	21.70	6,333	11,399
								Dry coal		37.2	56.8	5.97	.64	4.94	72.82	1.04	14.59	7,002	12,604
								Pure coal		39.6	60.4		.68	5.25	77.44	1.11	15.52	7,446	13,404
5445	SE. ¼ SE. ¼	6	12	89	14' 8''	8' of the upper bench.	4.5	As received	14.3	31.8	48.9	5.00	.46	5.62	60.70	1.02	27.20	5,889	10,600
								Air dried	10.3	33.3	51.2	5.24	.48	5.36	63.56	1.07	24.29	6,167	11,099
								Dry coal		37.1	57.1	5.83	.54	4.70	70.82	1.19	16.92	6,871	12,368
								Pure coal		39.4	60.6		.57	4.99	75.21	1.26	17.97	7,296	13,134
5446	SE. ¼ SE. ¼	6	12	89	14' 8''	7' of the upper bench.	6.2	As received	15.2	32.8	48.5	3.51	.60	5.77	59.91	.98	29.23	5,849	10,528
								Air dried	9.6	35.0	51.7	3.74	.64	5.42	63.87	1.04	25.29	6,236	11,224
								Dry coal		38.7	57.2	4.14	.71	4.81	70.66	1.16	18.52	6,898	12,416
								Pure coal		40 3	59.7		.74	5.02	73.71	1.21	19.32	7,196	12,953

5340	SE. ¼	4	17	90	11'+		8'...............	1.9	As received ...	13.6	34.6	43.1	8.69	1.44	5.53	58.79	.89	24.66	5,744	10,339
									Air dried......	11.9	35.2	44.0	8.86	1.47	5.42	59.93	.91	23.41	5,855	10,539
									Dry coal......	....	40.0	49.9	10.06	1.67	4.65	68.06	1.03	14.53	6,650	11,970
									Pure coal......	....	44.5	55.5	....	1.86	5.17	75.67	1.14	16.16	7,394	13,309
5324	NE. ¼ SW. ¼	6	20	88	8'		....	2.3	As received....	19.2	36.5	40.5	3.78	.34	5.74	58.88	1.34	29.92	5,401	9,722
									Air dried......	17.3	37.3	41.5	3.87	.35	5.61	60.27	1.37	28.53	5,528	9,951
									Dry coal......	....	45.1	50.2	4.68	.42	4.47	72.87	1.66	15.90	6,684	12,031
									Pure coal......	....	47.3	52.7	....	.44	4.69	76.45	1.74	16.68	7,012	12,622
5298	NW. ¼ SW. ¼	12	15	92	7'	9"	2' 1" from the upper bench.	5.8	As received....	20.7	36.0	33.4	9.90	1.11	5.44	51.84	.72	30.99	4,843	8,717
									Air dried......	15.8	38.2	35.5	10.51	1.18	5.10	55.03	.76	27.42	5,141	9,254
									Dry coal......	....	45.3	42.2	12.48	1.40	3.96	65.36	.91	15.89	6,106	10,991
									Pure coal......	....	51.8	48.2	....	1.60	4.52	74.68	1.04	18.16	6,977	12,558
5342	NW. ¼ SW. ¼	12	15	92	7'	9"	4' 11" from the two lower benches.	6.5	As received....	25.0	46.8	20.7	7.51	.39	5.55	51.13	.73	34.69	4,680	8,424
									Air dried......	19.8	50.0	22.2	8.03	.42	5.17	54.68	.78	30.92	5,005	9,010
									Dry coal......	....	62.4	27.6	10.02	.52	3.70	68.21	.97	16.58	6,243	11,237
									Pure coal......	....	69.3	30.7	....	.58	4.11	75.80	1.08	18.43	6,938	12,488
5448	NE. ¼ NE. ¼	23	13	91	6'+		6'...............	9.8	As received....	24.0	28.5	39.4	8.1	.97	....	....	....	....	4,499	8,098
									Air dried......	15.7	31.6	43.7	9.0	1.08	....	....	....	....	4,988	8,977
									Dry coal......	....	37.5	51.8	10.7	1.28	....	....	....	....	5,919	10,654
									Pure coal......	....	42.0	58.0	....	1.43	....	....	....	....	6,626	11,927
5447	SW. ¼	24	13	91	16'	5"	6' from bottom of lower bench.	12.8	As received....	26.0	30.1	37.9	6.0	1.01	....	....	....	....	4,641	8,354
									Air dried......	15.2	34.5	43.4	6.9	1.16	....	....	....	....	5,322	9,580
									Dry coal......	....	40.7	51.1	8.2	1.37	....	....	....	....	6,273	11,291
									Pure coal......	....	44.3	55.7	....	1.49	....	....	....	....	6,832	12,297
5299	SE. ¼ SE. ¼	4	16	92	2'	2"+	2' 2"............	1.7	As received....	10.3	22.2	57.7	9.83	.87	2.72	67.94	.77	17.87	5,752	10,354
									Air dried......	8.7	22.6	58.7	10.00	.89	2.57	69.12	.78	16.64	5,851	10,533
									Dry coal......	....	24.8	64.3	10.95	.97	1.76	75.71	.86	9.75	6,410	11,538
									Pure coal......	....	27.8	72.2	....	1.09	1.98	85.02	.96	10.95	7,198	12,957

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[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

6642. Carbondale mine. Sample from wall of room about 30 feet from main entry.

6644. Stemp Springs mine. Sample taken from wall of irregular room about 10 feet from minor entry.

6803. Linde opening. Sample taken on main entry about 40 feet from entrance.

6643. Lucksinger opening. Sample from breast of main entry.

5444. Martin mine. Sample taken in entry 430 feet from mouth of mine.

5449. Darling mine. Sample taken in entry driven to left 120 feet from main entry and 265 feet from mouth of mine.

5445. Angier mine. Sample taken in main entry of old workings 210 feet from mouth of the mine.

5446. Angier mine. Sample taken in old workings on left 300 feet from main entry and 440 feet from mouth of mine.

5340. Robertson mine. Sample taken from left side of room 50 feet from mouth of mine.

5324. Nebraska mine.

5298. Muddy Bridge opening. Sample on north wall of entry 35 feet from mouth of mine.

5342. Muddy Bridge opening. Sample on north wall of entry 20 feet from mouth of mine.

5448. Prospect. Sample taken from north wall 40 feet from entrance.

5447. Prospect. Sample taken from east wall 145 feet from entrance.

5299. Prospect. Sample taken from south wall 25 feet from entrance.

MESAVERDE COAL.

The Mesaverde formation contains the best coal in the field. Coal from this formation is now being mined in Wyoming at Rock Springs and Superior, and in Colorado in Routt County and from Newcastle to Crested Butte. The Mesaverde coal is probably more easily and economically minable than that of either of the other coal-bearing formations, owing to its prevailing low dips. This advantage may possibly be offset in many places by minor faults of a few feet displacement. The coal, which is bituminous, is very hard, rather brittle, with an almost metallic luster and a tendency to conchoidal fracture. The bedding is obscure and there is little or no cleavage. At the Stemp Springs, Carbondale, and Lucksinger openings there is a well-marked series of rifts or slips in one direction perpendicular to the bedding. In a very few places a less distinct system is present which is perpendicular to the bedding and approximately at right angles to the first system. These rifts, of which advantage is taken in shooting down the coal, dip from 65° to 90° and are not evenly spaced or continuous. Many of them show slickensides, and in the Lucksinger opening a few contain a thin film of pyrite and a very few show one-eighth to one-half inch of crushed coal. The coal is mined and handled with a small percentage of breaking and resists weathering well. A sample from the Lucksinger opening which had laid in an open shed for seven months was black, hard, and firm, with submetallic luster, no cleavage, slight conchoidal fracture, and no signs of weathering beyond a certain amount of peacock coloring. In thoroughly weathered surface exposures the coal breaks into rusty-brown cubes 4 or 5 inches on an edge, and these in turn break into very small cubes with black submetallic faces. The general character of the Mesaverde coal beds is shown in the following sections:

Sections of coal beds in the Mesaverde formation in the Little Snake River field, Wyoming.

No. on Pl. XIII.	Laboratory No.	Location.				Section of coal bed.	Ft.	in.	Name of mine or character of opening.
		Quarter.	Sec.	T.	R.				
		SE. ¼ NW. ¼.	[a]16	12	87	Sandstone, white. Coal Shale, bituminous Coal, bottom not exposed.	 1 2 3	 2 2 4+	Surface exposure.
		SW. ¼.	[a]17	12	87	Roof not exposed. Coal, badly weathered. Floor not exposed.	 6		Surface exposure.
1	6642	SE. ¼ SW. ¼.	7	13	87	Shale, sandy. Coal, good Fire clay Shale.	 2 4 6	 10 10	Carbondale mine.
		NW. ¼ NW. ¼.	32	13	87	Coal, good	2	10	Surface exposure.

[a] Colorado.

Sections of coal beds in the Mesaverde formation in the Little Snake River field, Wyoming—Continued.

No. on Pl. XIII.	Laboratory No.	Location.				Section of coal bed.			Name of mine or character of opening.
		Quarter.	Sec.	T.	R.		*Ft.*	*in.*	
3	6803	SE. ¼ SW. ¼.	8	12	88	Shale.			Linde opening.
						Coal, hard	8		
						Shale.			
4	6643	SE. ¼ NE. ¼.	[a]18	12	88	Coal, good	12	2	Lucksinger opening.
						Shale.			
2	6644	NE. ¼ SW. ¼.	13	13	88	Shale, sandy, slabby.			Stemp Springs mine.
						Coal, good	2	10	
						Bone.			
		SE. ¼ SE. ¼.	36	13	88	Shale, bituminous, blue to black.			Surface exposure.
						Coal, good	1	8	
						Shale	15		
						Coal, good	2		
							18	8	
6	5449	SW. ¼ SE. ¼.	5	12	89	Shale.			Darling mine.
						Coal, good	7		
						Shale	1		
						Coal, good	7	6	
						Shale	1	2	
						Coal.			
							16	8	
7	5445 5446	SE. ¼ SE. ¼.	6	12	89	Shale.			Angier mine.
						Coal, good	11		
						Sandstone	2		
						Coal, fair	1	8	
						Shale.			
							14	8	
17		NE. ¼ NE. ¼.	8	12	89	Shale.			Prospect.
						Coal	9		
						Shale.			
5	5444	SW. ¼ NW. ¼.	9	12	89	Shale.			Martin mine or Company bank.
						Coal	8		
						Shale.			
		SW. ¼ SW. ¼.	13	12	89	Shale, bluish	3		Surface exposure.
						Coal, fair	5		
						Sandstone, calcareous	8		
							16		
18		SW. ¼ SE. ¼.	32	13	89	Coal, brown	1		Prospect.
						Coal, good	3		
							4		
		NW. ¼ NE. ¼.	7	14	89	Shale.			Surface exposure.
						Coal	4		
						Shale.			
		NW. ¼ NE. ¼.	23	14	89	Shale.			Surface exposure.
						Coal	3		
						Shale.			
		SE. ¼ SW. ¼.	32	14	89	Sandstone.			Surface exposure.
						Coal, fair	6		
						Shale.			
		NW. ¼ NW. ¼.	33	14	89	Shale.			Surface exposure.
						Coal	3		
						Shale.			
		NW. ¼ SW. ¼.	33	14	89	Shale.			Surface exposure.
						Coal	2		
						Shale.			
		SE. ¼ NW. ¼.	13	14	90	Shale.			Surface exposure.
						Coal	2	7	
						Coal.			

[a] Colorado.

Sections of coal beds in the Mesaverde formation in the Little Snake River field, Wyoming—Continued.

No. on Pl. XIII.	Laboratory No.	Location.				Section of coal bed.			Name of mine or character of opening.
		Quarter.	Sec.	T.	R.		*Ft.*	*in.*	
		SE. ¼ NE. ¼.	15	15	90	Coal, fair Shale and sandstone Coal Shale Coal, good	2 20 5 15 15 57		Surface exposure.
		NW. ¼ SW. ¼.	22	15	90	Sandstone. Coal, good, hard Shale.	 5		Surface prospect.
		NE. ¼ NE. ¼.	18	16	90	Shale. Coal Shale.	 4		Surface exposure.
		NW. ¼ NE. ¼.	28	16	90	Shale. Coal Shale.	 4	 3	Surface exposure.
	5340	SE. ¼.	4	17	90	Sandstone, shaly. Coal, good Bottom not exposed.	 11		Robertson mine.

"LARAMIE" COAL.

As stated in a previous paragraph, it was possible to make only a few observations on the coals of the "Laramie" formation in the Little Snake River field, and no samples for analysis were obtained. Where observed, the unweathered coal has a submetallic luster and parts readily along the bedding planes, which are rather prominent. As weathering progresses this tendency to split along the bedding planes increases and vertical joints develop until the coal breaks readily into small plates, with the vertical planes black and lustrous and the horizontal planes yellow or rusty brown.

Sections of coal beds in the "Laramie" formation in the Little Snake River field, Wyoming.

No. on Pl. XIII.	Location.				Section of coal bed.			Name of mine or character of opening.
	Quarter.	Sec.	T.	R.		*Ft.*	*in.*	
8	SW. ¼ NE. ¼	15	12	90	Sandstone. Coal, good Shale.	 6	 6	Prospect.
	SE. ¼ SE. ¼.	15	13	90	Sandstone, massive Shale, gray Coal Shale, gray Sandstone, gray, shaly Shales, gray and brown Coal, brownish Shale, bituminous	15 2 2 1 3 3 1 28	 3 9	Surface exposure.
	SW. ¼ SW. ¼.	19	18	90	Coal	15+		Surface exposure.
	SE. ¼ SE. ¼.	7	15	91	Sandstone, gray Shale, brown, gypsiferous Coal Shale, brown Coal Bottom not exposed.	3 1 1 4 10	 6 10 4	Surface exposure.

"UPPER LARAMIE" COAL.

The "Upper Laramie" formation probably contains more coal than any other formation in the field. The coal is of about the same grade as that in the "Laramie," but is of lower calorific power, air slacks much more rapidly, and breaks down more easily in mining and handling than the Mesaverde coal. The nearest point at which it is mined extensively is Hanna, Wyo. The unweathered coal is black in the lowest member and in most of the uppermost member, but in places thin beds of impure coal with a brownish tinge are found near the top of the formation. As a rule the coal is rather light in weight and has a submetallic to resinous luster. Many beds are gypsiferous and a small amount of pyrite is common. It splits readily along the bedding planes and on weathering develops two secondary joint systems approximately at right angles to the bedding and to each other, so that the weathered coal breaks into little shaly blocks, all of whose faces are apt to be coated with a film of selenite or ferrous sulphate.

Sections of coal beds in the basal member[a] *of the "Upper Laramie" formation in the Little Snake River field, Wyoming.*

Laboratory No.	Location.				Section of coal bed.			Name of mine or character of opening.
	Quarter.	Sec.	T.	R.				
5448	NE. ¼ NE. ¼.	23	13	91	Shale, gray.	*Ft.*	*in.*	Prospect.
					Bone		4	
					Coal, dirty	6		
					Bottom not exposed.			
						6	4	
5447	NE. ¼ SW. ¼.	24	13	91	Sandstone, clayey.			Prospect.
					Coal, dirty	3	2	
					Bone		3	
					Coal, dirty		10	
					Bone		2	
					Coal	12		
					Shale, bituminous.			
						16	5	
	SW. ¼ NE. ¼.	25	13	91	Coal	3	8	Prospect.
					Bottom not exposed.			
	SE. ¼ NW. ¼.	25	13	91	Roof not exposed.			Prospect.
					Coal, good	5	2	
					Dirt		2	
					Bottom not exposed.			
						5	4	
	SE. ¼ SW. ¼.	7	17	91	Burned beds.			Surface exposure.
					Coal	2		
					Burned beds, approximately	20		
					Coal, good	4		
						26		
	SW. ¼ SW. ¼.	7	17	91	Shale, brown.			Surface exposure.
					Coal, good	2		
					Shale, brown.			

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[a] For section from uppermost member see Bull. U. S. Geol. Survey No. 341, p. 252 ("Creston, 9 miles south of; Coalbank Spring; NE. ¼ NW. ¼ sec. 3, T. 18 N., R. 92 W.")

Sections of coal beds in the basal member of the "Upper Laramie" formation in the Little Snake River field, Wyoming—Continued.

Laboratory No.	Location.				Section of coal bed.			Name of mine or character of opening.
	Quarter.	Sec.	T.	R.		*Ft.*	*in.*	
	SW. ¼ SW. ¼.	33	18	91	Sandstone, shaly.			Surface exposure.
					Shale, bituminous	2		
					Coal		3	
					Shale, bituminous		5	
					Coal	4	6	
					Clay, brown		8	
					Shale, bituminous		2	
					Coal	1	6	
					Clay, sandy, compact.			
						9	6	
5298	NW. ¼ SW. ¼.	12	15	92	Shale, bituminous		6	Muddy Bridge opening.
					Shale, brown		5	
					Coal	2	1	
					Shale, gray		9	
					Coal	2	5	
					Shale		2	
					Coal, slightly dirty	2	4	
						8	8	
5299	SE. ¼ SE. ¼.	4	16	92	Coal, burned	15		Prospect.
					Shale	3		
					Coal	2	2	
					Bottom not exposed.			
						20	2	
	SE. ¼ SE. ¼.	9	16	92	Sandstone, massive.			Surface exposure.
					Shale, bituminous, with thin beds of coal	3		
					Shale, gypsiferous	20		
					Sandstone, brown	1		
					Shale, bituminous	3		
					Coal, gray, shaly	1		
					Shale, gray	10		
					Coal	2		
					Shale, gray	4		
					Coal	14		
					Sandstone, grayish brown	4		
					Sandstone, light brown	1		
					Shale	10		
					Coal	5		
					Shale, gray	1	6	
					Sandstone, white	2		
						81	6	
	SW. ¼ SE. ¼.	10	16	92	Sandstone, light brown.			Surface exposure.
					Coal, good	2		
					Shale, gray	12		
					Coal, good	2	2	
					Shale, gray	2		
					Coal, good	1		
					Sandstone.			
						19	2	

BURNED COAL BEDS.

The thickness and character of many of the coal beds are obscured by burning along the outcrop. The burning is of relatively small extent in the Mesaverde, but much more prevalent in the "Laramie" and "Upper Laramie" coal beds. The most prominent effect is the production in many places of bright-red outcrops, the color being due to the alteration of the iron in the rocks adjacent to the burned bed. Whether or not the neighboring rocks are reddened they are as a rule more or less sintered, the distance to which coloration and sintering extend varying from almost nothing to several feet from the actual seat of burning. A quarter of a mile southeast of Muddy Bridge a small caved drift in the "Laramie" formation exposes about 18 inches of bituminous shale underlain by a few feet of dirty coal. Near by the bituminous shale has been burned, causing baking, reddening, and slumping of the overlying shaly sandstone, but the dirty coal composing the lower part of the bed is apparently not affected. In this connection attention should be called to the fact that sample 5299 in the table on page 206 was taken from a 2-foot bed separated by 3 feet of shale from 15 feet of burned coal. The physical appearance of the bed sampled was not altered by the burning, but the chemical analysis shows decided differences between this sample and the others collected from the same zone—notably increased fuel value, lower air-drying loss, lower volatile matter and higher fixed carbon giving higher fuel ratio, and, in the ultimate analysis, lower hydrogen and oxygen and higher carbon. Thus the coal in close proximity to a burned bed has by alteration become of considerably higher grade than its unaffected neighbors.

COKING.

So far as known the only coking test made on coals in this field was made on the Mesaverde coal at the Stemp Springs property in August, 1907. The chemical composition and physical characteristics show this to be among the very best coals in the region. The coking test was made in a regulation beehive oven 12 feet in diameter and 6 feet high in the arch. The floor was 2 feet thick, with air spaces. Reports of the test state that the fire burned on top and refused to go down, this condition being attributed to inexperienced firing and to the cooling action of the air spaces in the floor. The result was ash on top, unburned coal at the bottom, and some coke in the middle. This coke is stated to have analyzed 87 per cent of fixed carbon, 9 per cent of ash, and 4 per cent of moisture. In contemplation of a test in the near future the oven has been remodeled, with a 3-foot floor without air spaces, and the materials have been laid down for the construction of two new ovens. No report was made on the crushing strength of the coke obtained in the test, nor on the ratio of coal to coke produced.

DEVELOPMENT.

HISTORY AND PRESENT OPERATIONS.[a]

Early openings.—Doubtless the first coal opening in the Little Snake River field was made in 1863 by the Overland Stage Company a short distance east of Sulphur. The coal from this opening was used for blacksmithing and heating at the Sulphur stage station, and small quantities are said to have been shipped for blacksmithing purposes as far east as Denver and as far west as Fort Bridger. After the completion of the Union Pacific Railroad an opening is said to have been made by the United States Government just west of Muddy Creek about 3 miles south of Muddy Bridge, the coal being used in connection with stations on the stage road that ran from Rawlins to the White River Indian Agency, Colo. The first opening made by individual enterprise is reported to have been the Easom mine (NE. ¼ NE. ¼ sec. 8, T. 12 N., R. 89 W.; No. 17[a]), situated between the present locations of the Company bank and the Darling mine. It was opened in 1876 or 1877, but the land was never patented and work was abandoned in the late nineties.

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[a] For many of the statements regarding the history and development of the field the writers are indebted to Mr. H. F. Angier, Mr. M. W. Dillon, and Mr. John C. Friend.

Carbondale mine.—The earliest opening that is still in operation seems to be the Carbondale mine, in the SE. ¼ SW. ¼ sec. 7, T. 13 N., R. 87 W. (No. 1). Coal was discovered at the present site of the mine in the early eighties by Frank Fernald and Joe Hartenberg, and the mine was opened by George Doane to supply coal for mining operations in the Sierra Madre. Unsuccessful efforts were made to find coal nearer to the point of consumption. In the summer of 1908 the property was producing about 10 tons a day, employing seven men, using drilling machines, and shooting from the solid. The maximum extent of the workings from the outcrop at that time was about 1,300 feet, but the actual depth below the surface is slight throughout. The greater part of the original workings was abandoned in 1904, owing to difficulty with water and to irregularities in the coal bed caused by minor faults, and a new drift was started in March, 1908. The rooms are 12 by 20 feet, with stulls from 1½ to 2½ feet apart. The property is now owned by the United Smelters, Railway and Copper Company.

Stemp Springs mines.—The Stemp Springs mine (NE. ¼ SW. ¼ sec. 13, T. 13 N., R. 88 W.; No. 2) is owned by the Stemp Springs Coal and Power Company, the product being used in mining and smelting operations in the mountains to the east. The main entry is carried 6 feet high in the clear in coal, the rooms and pillars are irregular in size and shape, and stulls are set in the rooms from 3 to 6 feet apart. The main entry is driven just off the dip, which is about 2° and somewhat irregular.

Lucksinger opening.—The Lucksinger opening (SE. ¼ NE. ¼ sec. 18, T. 12 N., R. 88 W., Colorado; No. 4) has been operated for a number of winters by different persons, supplying coal for domestic use to the ranchmen of the upper Little Snake River valley. The coal has been mined from two large, somewhat irregular, more or less parallel drifts, no rooms being turned and very little timber being used.

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[a] Numbers refer to locations on Plate XIII.

Company bank.—The Company bank (SW. ¼ NW. ¼ sec. 9, T. 12 N., R. 89 W.; No. 5) formerly known as the Martin mine, is owned by the Snake River Coal Company. It was first discovered and opened about 1886 or 1887 by Noah Reader and has since produced about 10,000 tons, the present annual production being about 800 tons. The original entry runs as near the strike of the beds as the escarpment in which the coal bed outcrops will permit. Later entries run in directions successively approaching the north, the earlier entries being allowed to cave as the coal in their vicinity is worked out. The depth along the entries is a little more than 400 feet.

Darling mine.—The Darling mine (SW. ¼ SE. ¼ sec. 5, T. 12 N., R. 89 W.; No. 6), now owned by William Darling, was discovered and opened by Robert Turner and Ira Whiteaker in 1891 and later worked by Robert McIntosh. It has produced about 10,000 tons and is now producing about 800 tons annually. It is developed by an entry running for 265 feet nearly on the strike of the bed, which dips about 8°. From the main entry minor entries are run off to distances of 150 feet or so, and rooms of irregular size are turned from these entries.

Angier mine.—The Angier mine (SE. ¼ SE. ¼ sec. 6, T. 12 N., R. 89 W.; No. 7), on the opposite side of Savery Creek from the Darling property, was discovered and opened by Joseph Wilson in 1890 and is now owned by H. F. Angier. Its total production has been between 10,000 and 12,000 tons; its present annual production is from 800 to 900 tons. The original workings consist of a drift run 400 feet N. 45° W., from which at a depth of 145 feet a second entry runs 700 feet N. 53° W., the coal being worked out in rooms extending between these two entries. These workings are now abandoned, but a somewhat similar system of mining is being followed in the new opening about 100 feet south of the old one.

Dillon mine.—The Dillon mine, opened in 1886 but now abandoned, lies outside of the area especially considered in this paper, in the NE. ¼ NW. ¼ sec. 36, T. 21 N., R. 88 W.,[a] but was for a number of years one of the principal producers in the vicinity of the Little Snake River field, the coal being used in the neighboring town of Rawlins. Two main entries were driven, the earlier one being abandoned, partly because of the quantity of gas encountered. Drifts from the main entries were run at various angles, work being carried to a distance from the outcrop of over 500 feet. The mine was originally owned by M. W. Dillon, who states that it was abandoned in 1900 or 1901 by the people to whom he sold it because minor faults were encountered. The character of the faults may be judged from the following extract from a letter by Mr. Dillon: "The first fault is a downthrow of 4 feet, about 200 feet from the portal; the next is an upthrow of 4 feet, 240 feet from the portal; the next a downthrow of 6 feet, 450 feet from the portal."

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[a] Ball, Max W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, Plate XIII.

Nebraska mine.—The Nebraska mine (NE. ¼ SW. ¼ sec. 6, T. 20 N., R. 88 W.[a]) lies just outside of the Little Snake River field, in the part of the Great Divide Basin field covered by Ball in 1907. It is the only mine in or adjacent to the Little Snake River field which is in the "Laramie" formation, all the properties described above being in the Mesaverde. Mining is carried on throughout the winter months, the product being used in Rawlins, 7 miles distant. The dip of the bed varies from 12° to 20°. The coal is mined through a main entry, extending approximately down the dip, with entries turned at right angles from 100 to 200 feet apart.

Other openings.—In addition to the mines described above, there are in various parts of the field other openings, some of them supplying coal to one or two ranches in their immediate neighborhoods, others at present entirely abandoned or the scene of desultory prospecting. The Robertson mine (SE. ¼ sec. 4, T. 17 N., R. 90 W.; No. 16), in the Mesaverde, just east of Sulphur, has been worked to a depth of about 100 feet, 50 feet of which is a drift and the remaining 50 feet an irregular chamber. The Linde opening (SE. ¼ SW. ¼ sec. 8, T. 12 N., R. 88 W.; No. 3), also in the Mesaverde, has been worked to a depth of about 40 feet by a single straight, well-timbered drift. The Muddy Bridge opening (NW. ¼ SW. ¼ sec. 12, T. 15 N., R. 92 W.; No. 14), in the "Upper Laramie," is an irregular, practically untimbered opening about 40 feet deep, sloping about 25°. The Corlett opening (SE. ¼ SE. ¼ sec. 4, T. 16 N., R. 92 W.; No. 15), also in the "Upper Laramie," has been carried about 40 feet down a slope of 35°. A few miles northeast of Baggs, in Coal and Cutoff gulches, are a number of openings in the "Upper Laramie" (Nos. 9, 10, 11, and 12), of various depths up to 150 feet or more, none of which are operated at present. No. 10 is an excellently timbered slope dipping 25°, at present nearly full of water. No. 9 is also well timbered and nearly horizontal, but the coal is powdery. No. 11 is a drift approximately 150 feet deep, with coal as roof and no timbering. No. 12 is an irregular opening partly caved. The prospect opposite the Deary ranch (SW. ¼ NE. ¼ sec. 15, T. 12 N., R. 90 W.; No. 8) is in the "Laramie." It is an irregular slope about 30 feet deep, with a small amount of timbering.

FUTURE DEVELOPMENT.

The rapidity with which this field will be developed depends almost entirely on four factors—market, transportation facilities, timber supply, and water supply.

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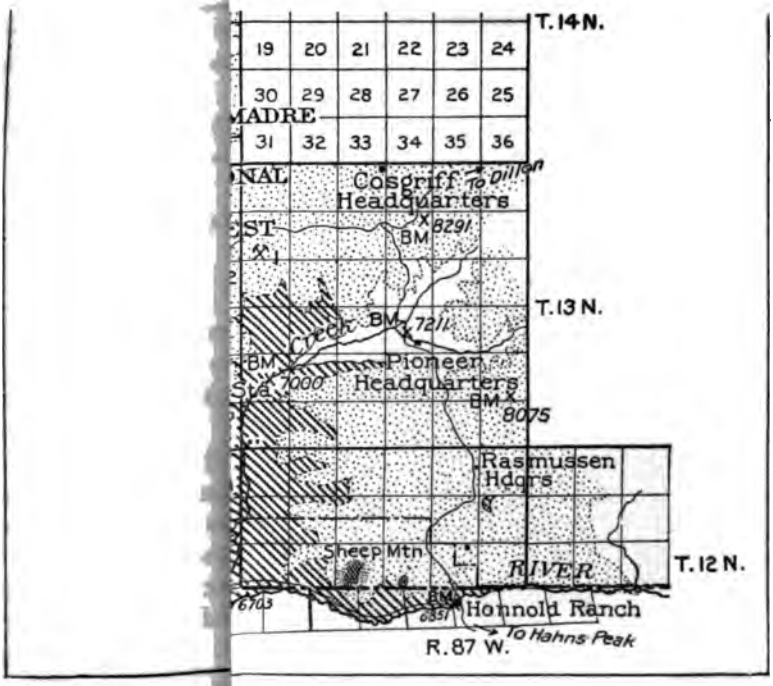
[a] Ball, Max W., The western part of the Little Snake River coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, Plate XIII.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EST
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Creek
BM 7211
BM
Sta. 7000
Pioneer Headquarters
BM 8075
Rasmussen Hdqrs
Sheep Mtn
RIVER
T. 12 N.
6703
BM 6851
Honnold Ranch
To Hahns Peak
R. 87 W.

MARKET.

The field is unfortunate in being surrounded by producing areas which are more accessible and in having its most available coals farthest from the railroads and from any present market. To the west are the Rock Springs and Uinta County fields, to the east is the Hanna field, and to the south are the Yampa and Grand Hogback fields of Colorado. On the other hand, the demand from the country to the west is so great that the Union Pacific Coal Company has in the last few years ceased shipping its Wyoming coal east, leaving unsupplied a vigorous demand in Omaha and adjacent towns. Denver, although in the vicinity of large coal fields, is a ready market for coal of this grade, and Salt Lake City is using all the coal mined commercially at Rock Springs and most of that in Uinta County, with no apparent danger of overstocking. On the whole, the demand for coal is greater than the supply, and the rapid development of the West is increasing the demand constantly.

The natural local market for the coal of the southern part of the field is in the mining districts in the mountains along the eastern border of the coal-bearing area. On both sides of the crest of the Sierra Madre, just east of the Carbondale and Stemp Springs mines, is the Encampment copper district, to which the coal from those properties is now being hauled. Further development of that district or of any of the prospective mining camps on the headwaters of Little Snake River would call for further development of the coal field. The great need of the smelters in the Encampment vicinity is for coke, and this the coals of the Little Snake River field have not yet been able to supply commercially, but they can supply an excellent steaming coal for power and mining operations.

TRANSPORTATION.

The field has at present no railroad, consequently no coal is produced within the field for consumption outside of it except that hauled by wagon from the Carbondale and Stemp Springs properties to the adjacent mining camps. The nearest railroad is the Union Pacific, about 12 miles to the north of the area especially treated in this paper and some 50 miles from the region of greatest present development. Approximately 50 miles southeast of the area is Steamboat Springs, Colo., the present terminus of the Denver, Northwestern and Pacific Railway, more commonly spoken of as the "Moffat road." It is planned to push this road westward through the Yampa field to Craig, Colo., within 37 miles of Baggs.

The Union Pacific Railroad Company is contemplating a branch from the main line southward to Craig. The starting point of the branch is still uncertain. It may be Rawlins, Creston, or Wamsutter. In any case the road will traverse this field from north to south. A line connecting the field with the "Moffat road" at Steamboat Springs is also discussed, to run through the Hahns Peak region and traverse the upper Little Snake River valley. Still another line which may be constructed is the rumored branch of the Laramie, Hahns Peak and Pacific Railway from Hahns Peak, the road being now under construction some 30 miles west of Laramie.

If a railroad is constructed through the field it will be comparatively easy to reach the coals by spurs. The flat-lying coal beds along Little Snake River from the mouth of Savery Creek upstream would be on any line traversing the valley, and a line from Baggs or Dixon would have a water-level grade. Construction of spurs to some of the coals lying in the higher Mesaverde ridges and plateaus might involve moderate engineering difficulties, but most of them could be developed by tracks laid in the dissecting canyons. No difficulty should be experienced in tapping the coals of the "Laramie" and "Upper Laramie" formations even in the higher parts of the hogback region.

TIMBER SUPPLY.

The fact that most of the coal beds of the field lie under shale roof makes the quality and price of timber an important item in any estimate of mining costs. The cost of timber at the Carbondale mine in the summer of 1908 is reported as about 15 cents to the ton of coal mined. The greater part of the field in Wyoming is devoid of timber, except for a few scattering scrub cedars in the Mesaverde ridges and a few cottonwoods along the river. East of Savery Creek, however, much of the country is well timbered. The Hayden National Forest includes Battle Mountain and extends northward and eastward across the Sierra Madre. The timber in most of the forest is estimated by the Forest Service [a] at less than 2,000 board feet to the acre, although part of it is estimated to carry between 2,000 and 5,000 board feet.

The part of the field in Colorado lies almost entirely within the Routt National Forest and is most of it heavily forested. The timber available in the southeastern part of the field is thus capable of supplying the needs of very extensive mining operations.

WATER SUPPLY.

In general, those streams which head in the formations younger than the Mesaverde are intermittent, and those which head in the Mesaverde or older formations are permanent either throughout their courses or while crossing and for some distance after leaving the older formations. Thus Savery and Battle creeks and their tributaries are permanent streams throughout; Muddy, Cow, Wild Cow, and Cherokee creeks become intermittent some distance after leaving the Mesaverde; and Dry Cow, Red, and Cottonwood creeks are intermittent throughout. The one younger formation which is strongly water bearing is the Bishop (?) conglomerate, which furnishes much of the water in Savery and Battle creeks and in the headwaters of Muddy Creek. Springs along the base of this formation and in the limestone, where limestone makes up the overlying beds, are rather numerous for the semiarid regions, and the quality of the water is excellent. Another stratigraphic location which shows a tendency to develop springs is the boundary between the Mesaverde formation and the Lewis shale. The springs at this horizon, however, are as a rule rather small and many are highly mineralized, particularly the sulphur springs in the vicinity of Sulphur. In the streams the alkalinity decreases and the quality of the water correspondingly improves as the flow becomes permanent. The water of Little Snake River itself is normally clear and of good quality. The waters of lower Muddy Creek and the lower courses of its tributaries are unfit for either human or boiler use.

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[a] Sierra Madre folio, Atlas Nat. Forests U. S., U. S. Forest Service.

So far as was ascertained the only wells in the field are sunk in the alluvium of the stream valleys. The water in these is of uncertain quality. Thus a well 20 feet deep at Muddy Bridge yields good water, but wells from 10 to 40 feet deep at Baggs and Dixon have developed water more alkaline than that in the river. It should be possible to supply small temporary operations by sinking shallow wells in the alluvium of almost any of the main stream valleys, even where the stream itself is intermittent. For deep wells the Mesaverde is the most promising formation in the coal-bearing area. Wells drilled into the westward-dipping part of this formation should yield an abundance of good water. The supply of water to be obtained from wells in the "Laramie" and "Upper Laramie" formations can best be judged by the wells of the Union Pacific Railroad north of the field. At a number of places between Rawlins and Tipton water was obtained at depths of about 500 feet in the "Laramie" and overlying formations, but it was too alkaline to be serviceable. At depths of 1,400 to 1,600 feet alkaline water usable for boiler and domestic purposes is obtained in the "Upper Laramie." In this field wells of that depth in the "Laramie" and "Upper Laramie should yield a plentiful supply of water of about the same grade as that obtained at Riner and Wamsutter. The basal member of the "Upper Laramie" should be the best water-bearing zone of the two formations. The two locations most favorable to the development of artesian water are in the Lewis shale valley at or near the Mesaverde boundary and in the valley formed in places by the middle or clay shale member of the "Upper Laramie," near the top of the lowest member. The two formations to be avoided are the shale immediately east of the Mesaverde and the Lewis shale except near the Mesaverde.

THE SOUTHERN PART OF THE ROCK SPRINGS COAL FIELD, SWEETWATER COUNTY, WYOMING.

By ALFRED R. SCHULTZ.

INTRODUCTION.

This report is a brief discussion of the economic geology of the southern part of the Rock Springs coal field, Wyoming. The survey on which the report is based was made during the summer of 1908 by John L. Rich, B. L. Johnson, George E. Burton, and the writer. A detailed report on the coal of the Rock Springs field will be prepared as soon as time and the work in hand will permit.

The primary object of the investigation was the classification of the public land with respect to its coal content. Economic considerations therefore demanded that the work be based primarily on Land Office subdivisions, and that all coal outcrops, prospects, and geologic data be located with respect to established government corners. In the summer of 1907 similar work was done in the northern part of the Rock Springs field,[a] and in a part of the Great Divide Basin coal field, extending northwestward from the Rawlins dome.[b] The work of the past season was a continuation of that of the preceding year. The mapping of the Rock Springs coal field was completed by the writer, while E. E. Smith completed the mapping of the Great Divide Basin field and closed the gap between the areas mapped in 1907.

The Rock Springs coal field is located in the central part of Sweetwater County, Wyo., on the east side of Green River, in the southern part of the State, the south end of the field being only a few miles north of the Wyoming-Colorado state line. (See Pl. XIV.) It lies in the midst of the great Wyoming desert and occupies the crest of a low structural dome. This eroded dome, with its surrounding rim of Tertiary beds, gives to the field a natural boundary with reference to the outcrop of the coal-bearing rocks. The productive formations, however, underlie much of the surrounding country in the Green

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[a] Schultz, A. R., Bull. U. S. Geol. Survey No. 341, 1909, pp. 256-282.
[b] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 220-242.

River Basin, which includes within its borders the most important coal fields along the Union Pacific Railroad between the Wasatch and Wyoming mountains on the west and the Rocky Mountains on the east.

The Union Pacific is the only railroad crossing this area and nearly all points in the Rock Springs field are readily accessible from the main line. Several projected lines have been surveyed across the north end of the field, but no other line has yet begun active construction. The location of the Union Pacific Railroad places it in a position to control the future development of the field. The grade along its line is moderate, and by short spurs with light grades, similar to those of the Superior and Gunn branches, it will be comparatively easy to reach all points at which mines may be opened to advantage. For all of the southern half of the field the most accessible routes lie along the main tributaries of Bitter Creek—Little Bitter, Killpecker, Salt Wells creeks and their tributaries. Spurs built up any of these valleys would be natural feeders to the trunk line along Bitter Creek.

The southern part of the Rock Springs field is covered by the public-land surveys. Because of an assumed poor survey a considerable tract, approximately 12 townships, was resurveyed by the General Land Office in 1906, and 24 townships were resurveyed by that bureau in 1907. In the part of the field south of the fourth standard parallel few corners could be found, and these do not agree among themselves; hence it is probable that they have not been authoritatively established. In this area it was found necessary to resurvey the townships before the land could be classified. During the summer of 1908 Tps. 15 and 16 N., R. 102 W., were resurveyed by the General Land Office and a detailed topographic map, with a contour interval of 50 feet, was made. The geologic work in these two townships was done by George E. Burton.

Glenn Smith, topographer of the United States Geological Survey, mapped in the summer of 1908 a 15-minute quadrangle in the vicinity of Rock Springs. The mapping of this quadrangle was done on the scale of 1 inch to the mile, the contour interval being 50 feet. Later in the season photographic copies of this base were used in mapping the geology and coal outcrops.

Of the territory outside of the areas of detailed mapping mentioned above, or approximately 10 townships, no maps other than township plats were available for field use. It was therefore necessary to make a topographic map as the geologic work progressed. In such territory all locations were made either (1) by pacing section lines or by making traverse from land corners found by such pacing, or (2) by plane-table station work, supplemented by plane-table traverse, triangulation, and intersection work, checked and tied to land corners.

In areas where no corners could be found plane-table control was used entirely, road and line stadia traverses being made wherever necessary.

Altitudes were carried by stadia, altimeter, Locke level, and aneroid, all being adjusted to the temporary and permanent bench marks along the line of levels run around the dome from Rock Springs north to Steamboat Mountain, thence south to Point of Rocks, Black Buttes, and around the south end of the dome back to Rock Springs. Lines were run one-fourth to one-half mile apart, and the outcrops of all the more important coal beds were traversed and the traverses tied to land corners. The field sheets were made on the scale of 2 inches to the mile, with a contour interval of 50 feet, and will be used in the preparation of the maps to accompany the final report. The maps (Pls. XIV and XV) accompanying the present report have been prepared from the field sheets, and although approximately correct they may differ in minor particulars from the final large-scale maps.

TOPOGRAPHIC FEATURES.

The Rock Springs coal field lies along the eastern margin of the Green River Basin and includes on the northeast a part of the Great Divide Basin. It occupies the major part of the Rock Springs structural dome, which is completely surrounded by Tertiary beds. Within this field there are five distinct topographic districts, each presenting entirely different characteristics from those of its neighbor. Only the most prominent peaks and ridges that encircle the dome rise above the adjacent Tertiary escarpments. The divide between the Green River and Great Divide basins has no topographic identity or distinctness. It lies for the most part several miles east of the dome and is formed in some places of Tertiary rock, in others of Cretaceous rock, and in still others of igneous rock. The divide is irregular, extending across several distinct topographic districts.

The principal topographic features of this field are due to (1) hard, resistant sandstone beds of the Mesaverde formation; (2) hard, resistant limestone and sandstone beds of the nearly horizontal Green River and Wasatch formations; (3) migrating sand; (4) soft beds of the Wasatch formation, Lewis shale, and shale underlying the Mesaverde in the central part of the dome; (5) gravel slopes of the Bishop conglomerate; and (6) igneous rock.

The hard, resistant sandstone of the Mesaverde makes notable concentric ridges or hills that are more or less continuous about the central portion of the dome. These ridges contain the most important coal beds of the field and are in general separated from one another and from areas of equally or more elevated younger rocks by belts of low relief. Two pronounced depressions are carved in the soft shale overlying and underlying the sandstone of the Mesaverde formation. These low valleys are natural routes of travel and afford easy access from the railroad to the more rugged ridges containing the coal. The shale below the Mesaverde gives rise to low relief in the central part of the Rock Springs dome and is the cause for the development of Baxter Basin.

The hard, resistant limestone and sandstone beds of the Green River and Wasatch formations produce notable table-like forms bounded by prominent escarpments of considerable length. In places the harder layers in these beds produce bench after bench in regular succession separated by nearly parallel valleys. In many places the more prominent ridges form bluffs and in parts of the field the beds present characteristic badland topography.

Huge dunes formed by migrating sand constitute the most conspicuous topographic feature in the northern part of the field.

The soft beds of the Wasatch form low depressions along the synclinal trough of the Great Divide Basin and along Killpecker Valley. This formation contains numerous beds of coal, few of which are well exposed, so that their presence over much of the region can only be inferred from a study of sections where it is better exposed. The topographic features in this area are such that the coal beds are readily accessible.

The long, gentle, grass-covered slopes of the hills capped by the Bishop conglomerate form a striking topographic feature and outline in a general way the peneplain that was formed immediately preceding the epoch marked by the deposition of this material.

The igneous rocks in this field rise like landmarks out of the arid plateaus of the Red Desert. The lava forming these rocks flowed from a little group of volcanoes far removed from the centers of igneous activity and spread out on a nearly horizontal surface. The evidence at hand seems to indicate that the surface upon which these lavas flowed is the same as the peneplain referred to above in connection with the Bishop conglomerate. Their nearly concentric cones, needle-like necks, irregular dikes, and table-like sheets afford a striking contrast to the topographic features of the surrounding hills.

The drainage of this area for the most part flows to the Pacific. The main streams are not affected by the Rock Springs dome, which in a way connects the Uinta and Wind River mountain ranges. The most prominent stream in this field is Bitter Creek, which controls the major part of the drainage of the dome. It flows across the central portion of the dome at nearly right angles to the major axis and has carved a broad valley along which the Union Pacific Railroad is constructed. The three largest tributaries of Bitter Creek—

Killpecker, Little Bitter, and Salt Wells creeks—have been shaped indirectly by the fold. On account of the difference in the hardness of the beds these valleys extend in the main along the strike of the beds and are approximately at right angles to Bitter Creek. In some places, as in the valleys of Salt Wells and Black Buttes creeks, the small streams cut across several of the ridges before joining the main stream, and one of the tributaries of Salt Wells Creek cuts three times across a pronounced hogback ridge 1,000 feet in height instead of following the softer shale along the strike of the beds.

At the south end of the dome the streams do not cut directly across the major axis. Red Creek, on the west side, drains southward into Green River after cutting a channel through part of the Uinta uplift. On the east side of the axis Vermilion Creek drains southeastward, paralleling the Uinta uplift through the upper half of its course, and finally cuts directly across part of this uplift and unites with Green River near the south end of Browns Park.

All the streams on the west side of the dome between Red Creek and Jack Morrow Creek not included in the Bitter Creek drainage basin are more or less nearly at right angles to the major axis.

GEOLOGY.

STRUCTURE.

GENERAL STATEMENT.

The structure of the Rock Springs field is comparatively simple. It consists of a huge dome of Cretaceous and Tertiary rocks which rise in the midst of the nearly horizontal rocks of the Green River basin and partly divide the southern portion into two smaller basins, the Bridger Basin on the west and the Red Desert or Washakie Basin on the east. The major north-south axis of the dome is approximately 90 miles long and is located close to the west limb of the anticline. The beds along this limb dip from 5° to 30° W.; those along the east limb dip from 5° to 10° E. The minor east-west axis is approximately 50 miles long, extending across the dome in a direction north of east and south of west, passing north of Aspen Mountain and through a point 4 miles north of Black Buttes, a station on the Union Pacific Railroad. Several small anticlines and synclines are developed upon the main dome, but for the most part they are unimportant. Two of the largest of these cross folds occur near the south end of the dome and are parallel to the minor axis and to the trend of the Uinta uplift. The oldest beds involved in this structure are exposed in the vicinity of Baxter, a station on the Union Pacific Railroad, and outcrop for a distance of about 30 miles along the crest of the dome.

Four coal groups are exposed in this area, and it is believed that *another* group is concealed by overlap of the youngest or stratigraphically highest coal group. Three of the four groups are more or less continuously exposed and lie somewhat concentrically around the non coal-bearing central part of the dome; the other is exposed only in the northern two-thirds of the east side of the dome. The structural relations of the two lower coal groups (Rock Springs and Almond) are those of two formations that are conformable and outcrop in concentric belts around the central portion of the dome. These two coal groups are separated from each other by white sandstone about 800 feet thick, well exposed at Point of Rocks.

The third or Black Buttes coal group rests conformably on the underlying formation and outcrops in a zone extending along the east side of the dome from T. 23 N., R. 103 W., southward to T. 17 N., R. 101 W. This zone is thought to be concentric with the outcrops of the underlying formations. Although no exposures of it have been seen on the west side of the dome, its beds are believed to be covered there by the Black Rock coal group, which rests in some places upon the beds of the second or Almond coal group and in others upon the white sandstone between the Rock Springs and Almond coal groups, and which in one place (T. 18 N., R. 105 W.) comes into contact with the Rock Springs coal group as a result of faulting. Along the east side of the dome the Black Buttes zone is separated from the Almond zone by a belt of non coal-bearing Lewis shale, which doubtless continues around the dome in the same way as the Black Buttes and Almond coal groups and underlying formations.

The Knobs-Cherokee coal group is not exposed in the Rock Springs dome, but is believed to be present between the Black Buttes and the Black Rock coal groups, probably extending around the dome in a belt that is somewhat concentric with those of the other groups.

The Black Rock coal group lies unconformably upon the Black Buttes and older coal groups and like them outcrops around the dome more or less concentrically with the others. In places this group conceals wholly or in part the underlying group. By far the most pronounced unconformity observed in the field occurs at its base. The Black Rock coal group occupies a large area in the northeastern part of the Rock Springs field and in the Great Divide Basin. The same group contains coal beds in the low synclinal trough between the Rock Springs dome and the Rawlins anticline.[a]

FAULTS.

The general dome or anticlinal structure is somewhat complicated by many normal faults of considerable throw. Here and there the horizontal displacement amounts to 3 miles; the vertical movement is usually less than 100 feet, but in a few localities reaches several hundred feet. Near the south end of the dome, in T. 14 N., R. 103 W., along the crest and south limb of a low anticline parallel to the Uinta uplift, is an overthrust fault which has a vertical displacement of 200 feet. The fault plane dips to the south about 20° from the horizontal, indicating that the thrust came from that direction.

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[a] See Bull. U. S. Geol. Survey No. 341, 1909, pp. 220-255.

Some of the faults extend across the dome, others cut only one limb or part of one limb, and still others extend for only a few hundred feet or a mile or two and then die out. Some of the larger faults have been traced for a distance of more than 20 miles. The general trend of the faults is nearly at right angles to the strike of the rocks or across the axis of the major anticline. In some places, however, the angle of departure is large and the fault parallels the strike more nearly than the dip of the beds. This is well illustrated near the north end of the dome, where the faults cut some of the rocks at right angles to their strike and before dying out continue approximately along the strike of the underlying beds. The position of the larger faults is shown on Plates XIV and XV. In addition to the larger faults readily detected on the surface, numerous small faults are encountered in mine workings. In the Rock Springs coal group, from the Van Dyke coal bed upward, there is at many places a system of characteristic joints or slips that cut the coal at short intervals from floor to roof. These slips incline toward the south, and along many of them there is displacement of one-half inch to a foot or more. As a rule these small faults do not interfere with mining, but rather assist in breaking or parting the coal, thereby making it easier to mine. The larger faults, however, greatly increase the difficulties of mining and tend to retard development work. In regions of much faulting the offsetting of the coal beds may so increase the cost that mining will be abandoned or development work stopped. The exact date of the faulting is not known. It may have occurred at various times during the gradual uplift of the dome after the close of the epoch of Cretaceous deposition. It is believed, however, that most if not all of the faulting is associated with the movements that gave rise to the leucite lava flows and renewed uplift in the Uinta Mountains immediately before the period of deposition of the gravel, which is entirely independent of the faults and folds in the underlying rocks.

STRATIGRAPHY.

OUTLINE OF GEOLOGIC HISTORY.

The beds of coal in the Rock Springs field and the rocks in which they occur form only a small part of the great sedimentary series that was deposited at a time when this part of the continent was largely submerged. The beds were deposited in a nearly horizontal position during the various stages of submergence and emergence under conditions ranging from those of a deep sea to those of shallow water or swamps, in waters that were salt, brackish, or fresh. The oldest rocks exposed in the Rock Springs dome are of Montana age. From the epoch of their deposition until the end of the Cretaceous no profound disturbance or broad orographic movements occurred in this region. There was a gradual change from deep-sea to shallow-water conditions, with oscillations back and forth, giving rise to swampy areas that were favorable for the accumulation of coal beds. From the marine stages of the lower Montana there is a regular succession upward through the brackish-water to the fresh-water stage. The strata, so far as can be seen, are entirely conformable and the series is complete. In late Cretaceous time the horizontal beds deposited in this region became involved in a movement which gave rise to the low anticlinal arch that subsequently developed into the Rock Springs dome. This period of gentle doming or warping was accompanied and succeeded by one of deposition in shallow fresh water, during which a series of beds, conglomeratic at the base and coal bearing throughout, were laid down upon the older marine and brackish-water beds and, in places along the margin of the rising dome, upon the eroded edges of the older rock. In succeeding epochs fresh-water beds in which no coal occurs were deposited to a large degree in lake basins.

After the deposition of the fresh-water beds movements of the earth's crust folded and broke the originally continuous Cretaceous and later sediments, so that it is necessary to study their attitude of superposition in order to determine the relation of the beds to one another. There are also evidences that during great time intervals deposits were not formed or that if laid down they were subsequently removed, leaving little or no record of their existence. Particularly is this true of post-Cretaceous time. After the fresh-water beds had been laid down there was a long epoch of erosion in which the entire region was reduced to a peneplain or nearly level surface. This was succeeded by mild volcanic activity, during which the leucite lava flows north and west of Rock Springs were poured out on a planed off, nearly level surface, formed by the truncation of the underlying rocks. This volcanic activity culminated in or accompanied orographic movements that resulted in rapid erosion and the deposition of an extensive gravel sheet over the entire region from the Uinta Mountains northward to Bitter Creek. This gravel sheet is independent of the folds and faults in the underlying rocks, which are beveled across entirely irrespective of either hardness or structure. From this gravel-covered plain the present topographic features have been carved in late Quaternary time, almost solely by erosion.

DESCRIPTION OF FORMATIONS.

The investigations of the Rock Springs field have shown that the subdivisions mapped by King and Powell can not be applied to the sequence of rocks in this region. A large collection of fossils obtained by members of this party and studied by F. H. Knowlton and T. W. Stanton indicates that the several formations have the geologic time values indicated in the accompanying table. In this table the general character and succession of the Cretaceous and Tertiary rocks, together with their economic importance, are set forth. As nearly all the rocks exposed in the Rock Springs dome are closely related to the coal-bearing rocks, the entire stratigraphic section is here presented.

Geologic formations of the Rock Springs field.

System.	Series or group.	Formation.	Economic designation.	Thickness (feet).	Description.	Economic value.
(?)	Post-Eocene.	Igneous.	Leucite lava.	0 to 350	Dikes, flows, volcanic necks, and agglomerate.	Potash niter occurs in some of these rocks.
		Bishop conglomerate.	Gravel.	0 to 200	Waterworn and subangular pebbles and bowlders, many of them from 1 to 6 feet in diameter, embedded in finer gravel and sand.	**Good water horizon.** Supplies many of the springs in southern part of field.
		Unconformity.				
Tertiary.	Eocene series.	Green River formation.		0 to 630	Massive, irregularly bedded sandstone; white, yellow, and brown shaly sandstone; some limestone and interbedded shale.	
		Unconformity.				
				0 to 950	Thin-bedded shale, sandstone, and limestones (some of which are oolitic); some dark-colored bituminous shale.	Contains traces of oil in bituminous shale. In places rock seems to have been burned in consequence of presence of oil.
		Unconformity.				
				0 to 800	Variegated clay, shale, and sandstone, in places slightly conglomeratic; produces highly colored escarpment of Laney Rim and Cathedral Bluffs.	
		Wasatch formation.		[illegible] to [illegible]	Thin fissile shale and sandstone, prominent oolitic limestone in places 20 to 50 feet thick near base; also other oolitic and concretionary beds locally resembling huge oyster shells scattered on surface.	

Geologic formations of the Rock Springs field—Continued.

System.	Series or group.	Formation.	Economic designation.	Thickness (feet).	Description.	Economic value.
Tertiary.	Eocene series.	Wasatch formation.	Black Rock coal group.	1,000 to 3,500	Alternating layers of white, yellow, and brown sandstones, and gray, drab, and carbonaceous shales, with coal beds and conglomerate containing granite and quartzite pebbles. Numerous bands of white concretionary sandstone, weathering in irregular shapes. Basal sandstone is conglomeratic. Sandstone hardens locally and weathers into forms resembling large log or spherical concretions. Large cross-bedded reddish sandstone forms badland topography in Red Creek valley and Fire Hole Basin.	**Coal bearing.** Many thin beds of coal and at least one bed 25 feet thick occurs in this group. No large mines opened on this coal. Prospects opened in these beds at many places around the dome.
		Unconformity.				
		"Upper Laramie" formation.	Knobs-Cherokee coal group.	6,000 to 9,400	Alternating layers of soft yellowish brown and white sandstones and drab, brown, and black shales. Not exposed in the Rock Springs dome.	**Coal bearing.** Several beds of workable coal occur in the upper portion near Cherokee and in the lower portion near Knobs. Regarding Cherokee and overlying coal beds see logs of Wamsutter wells, T. 20 N., R. 94 W., page 125.
		Unconformity.				
Cretaceous.	Montana group.	"Laramie" formation.	Black Buttes coal group.	1,500	Massive basal bed of white and yellow sandstone showing traces of conglomerate in places; forms prominent scarp; overlain by various sandstone, clay, and coal beds. Fossils abound in places. Exposed only in the northern part of the east side of the dome and here only lower part is visible. On west side of Rawlins dome this formation is 3,900 feet thick.	**Coal bearing.** Mines once worked on these beds near Hallville and Black Buttes station. New mine opened in 1907 south of Black Buttes. Prospects at various points. May yield artesian water.
		Lewis shale.		750	Dark-gray, drab, and black shales, highly gypsiferous, with some soft shaly sandstone and large concretions; some lenticular beds of white sandstone near base; produces topography of low relief.	Possible source of clay. Natural routes of travel. Not known to be coal bearing.
		Mesaverde formation.	Almond coal group.	700 to 950	Soft white and brown sandstones, sandy shale, and clay, with numerous beds of coal and bituminous shale.	**Coal bearing.** Many coal beds. Numerous prospects throughout the field. Coal from these beds has been mined at Rock Springs and Point of Rocks.

Geologic formations of the Rock Springs field—Continued.

System.	Series or group.	Formation.	Economic designation.	Thickness (feet).	Description.	Economic value.
Cretaceous.	Montana group.	Mesaverde formation.		800 to 1,000	Massive white and yellowish sandstone. Upper third conglomeratic, with fine black and gray quartz pebbles. Sandstone forms pronounced escarpments and hogback ridges, giving rise to the "white wall."	**Water bearing.** Yields artesian water in parts of field. Flowing wells at Point of Rocks. Wells northwest of Superior. Water will probably be encountered in these beds back from the outcrop all around the Rock Springs dome.
			Rock Springs coal group.	600 to 1,400	White to yellow sandstone, interbedded shale and clay, with several coal beds. The heaviest beds of sandstone are grouped near the base of the formation. Total aggregate thickness of coal in this group about 90 feet.	**Coal bearing.** Many large coal beds and numerous smaller beds. Best coal in the Rock Springs field. Important mines at Rock Springs, Sweetwater, Blairtown, Gunn, and Superior. Many prospects and drifts opened. Artesian-water zone. Flowing wells at Superior and Rock Springs.
				1,200 to 1,800	Drab, yellow, and brown sandstones and interbedded shale and shaly sandstone with little or no bituminous matter. Massive sandstones are grouped near top of formation, giving rise to the "golden wall."	**Water bearing.** Important artesian-water zone. This formation will probably supply water outside of the ridges and escarpments surrounding Baxter Basin.
				1,000	Black and drab shales, very soft and friable. Shaly sandstones and arenaceous shale, in places highly gypsiferous. Much of it very friable, producing low benches and ridges.	Possible source of clay. Considerable gypsum. In places some sulphur.

IGNEOUS ROCKS.

In the north half of the dome numerous intrusive and extrusive masses have been forced up through the Cretaceous and Tertiary rocks and cap these rocks in several localities. The exposures of leucite range from talus-covered hills, isolated volcanic necks, and associated dikes to lava flows with cones, intruded sheets, and dikes. Many of the lava sheets present abrupt walls from 50 to 100 feet in height. Some of the lava flows and volcanic necks lie along fault lines through which the molten mass may have found an outlet. In other localities the lava seems to have forced its way through the rocks without causing any disturbance. The sedimentary beds lie practically horizontal around the igneous masses, which contain many fragmentary inclusions of the country rocks. Although the lavas have cut many coal beds and rocks of the coal-bearing formations, in no place were the coal and igneous rock seen in actual contact. Coal samples Nos. 5597 and 5599[a] were collected from two prospect pits in sec. 10, T. 21 N., R. 102 W., a few rods below the overlying lava sheets and about a mile from several volcanic cones, but showed no apparent difference in physical or chemical properties from coals lying at a distance from the igneous rock. The exact age of these leucite flows has not been definitely determined. They are positively later than the Green River formation and may be considerably later. From the best evidence at hand it is believed that a period of mild volcanic activity followed the peneplanation mentioned in the outline of the geologic history.

NON COAL-BEARING ROCKS.

In the Rock Springs field there are several zones of non coal-bearing rocks below, between, and above the coal groups. Below the Mesaverde formation is an unnamed dark-gray to black shale of Montana age, which occupies the central part of the dome in Baxter Basin. This is the oldest rock exposed in the field. Above this shale and below the Rock Springs coal group occur sandy shale and sandstone, which form the lower beds of the Mesaverde formation. The upper of these beds gives rise to the main scarp surrounding Baxter Basin, often referred to as the "golden wall."

Between the Rock Springs and Almond coal groups is a massive white sandstone, well exposed at Point of Rocks, which contains here and there traces of bituminous matter and beds of coal from 2 to 18 inches thick. It is not, however, coal bearing in a commercial sense. The upper third is more compact and conglomeratic than the lower portion. This sandstone gives rise to the main scarp surrounding the Rock Springs coal zone, often referred to as the "white wall." In parts of the field this escarpment is from 200 to 500 feet high.

Between the Almond and Black Buttes coal groups is a mass of soft gray and drab shales, highly gypsiferous, which on weathering give rise to regions of low relief that furnish excellent natural routes for travel across the field. No trace of coal has been found in these beds.

Overlying the Black Rock coal group are four groups of beds which are not known to be coal bearing in this region. The lower two belong to the Wasatch formation, and the upper two to the Green River formation. The beds immediately overlying the Black Rock coal group consist of fissile shale, conglomerate, oolitic limestone, shale, clay, and sandstone. Some of the greenish-white shale of these beds is very fissile and closely resembles the shale in the lower part of the Green River formation. The second group of beds consists of red or varicolored conglomeratic sandstone, shale, and clay, which are well exposed in Laney Rim and Cathedral Bluffs, southwest of Wamsutter. The third group of beds belongs to the Green River formation and consists of white and green fissile shales, limestone, and sandstone similar to those so characteristic of the lower part of the Green River formation in other parts of the Green River Basin. At the south end of the dome, outside of the territory here described, traces of coal were found near the base of these beds, but throughout most of the field no coal was seen in them. The fourth group of beds also belongs to the Green River formation and consists of massive, irregularly bedded sandstone, sandy limestone, and shale that are well exposed north of Wilkins, a station on the Union Pacific Railroad, a few miles west of Rock Springs, and in the vicinity of the town of Green River. The same beds are present in small outliers on the east side of the dome in the vicinity of Pine Butte.

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[a] Bull. U. S. Geol. Survey No. 341, 1909, p. 272.

Overlying all these beds and obscuring many of them is a mantle of slightly indurated gravel (Bishop conglomerate) that extended originally over the entire region south of Rock Springs to the north flank of the Uinta Mountains. This material has been dissected by the streams until only remnants are left. The largest of these extends southward from Aspen Mountain to Miller Mountain (Tabor Plateau) and westward between the headwaters of Sage and Little Bitter creeks. Two other remnants of considerable size are found on Little Mountain (Quien Hornet of the Powell Survey) and on Pine Mountain (Bishop Mountain of the Powell Survey). The first is separated from Miller Mountain by the valley of Sage Creek and the second lies about 10 miles southeast of Miller Mountain. At many other localities small areas are capped by similar sheets of gravel lying at accordant elevations, which once formed parts of the sheet that mantled this entire region.

In this report all the non coal-bearing rocks are considered collectively and mapped in two patterns irrespective of their stratigraphic relations. All the beds above the coal groups are shown in stipple; those below and between the coal groups are shown in a parallel ruled pattern.

COAL-BEARING ROCKS.

GENERAL STATEMENT.

The oldest coal-bearing rocks exposed in this field are of Montana age. The Frontier formation[a] of the Colorado group, which contains the high-grade Kemmerer coals of Uinta County, although not outcropping in this area, is believed to be present and to contain workable beds of coal. It is also believed that along the axis of the dome in the vicinity of Baxter station these coals may lie near enough to the surface to be mined some day, but at present no borings have penetrated to a sufficient depth to reveal them, and the depth at which they may occur and even their existence are somewhat problematical.

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[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, p. 226. Schultz, A. R., Bull. U. S. Geol. Survey *No. 316, 1907, pp. 212-241.* Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 331-353.

The Mesaverde formation consists of four distinct members, two of which are coal bearing. The lowest member consists chiefly of sandstone, shaly sandstone, and shale, all of which are barren of coal and show no indications of carbonaceous matter. The two coal-bearing members of the Mesaverde are separated from each other by massive white sandstone 800 to 900 feet thick. The lower one of the Mesaverde is known as the Rock Springs coal group and the upper as the Almond coal group. The Almond coal group is overlain by the Lewis shale, and the remaining coal-bearing rocks exposed in the Rock Springs field are of post-Montana age. Above the Lewis shale, the upper formation of the Montana group, in the western part of the area are two groups of coal beds separated from each other by an unconformity of considerable magnitude. For convenience in the following discussion the lower has been called the Black Buttes coal group and the upper the Black Rock coal group. The unconformity between them may in places escape observation. The lower group of these post-Montana coal beds is of "Laramie" age; the upper group belongs to the Wasatch formation, and is therefore of Tertiary age. In the region to the east there occurs still another coal group at the base of the Tertiary, called undifferentiated Tertiary by Smith[a] in his report on the coal field of the Great Divide Basin. This group contains the coal beds at Knobs and Cherokee and in this paper it will be referred to as the Knobs-Cherokee coal group, or "Upper Laramie" formation. According to the paleobotanical evidence it is of Fort Union age and is the same as the "Upper Laramie" of central Carbon County, described by Veatch,[b] and the "Upper Laramie" of the Little Snake River field, described by Ball on pages 186 to 213 of this bulletin. It is exposed on the west side of the Rawlins dome, but does not appear at the surface in the Rock Springs dome, the entire formation being concealed by overlap of the Black Rock coal group.

ROCK SPRINGS COAL GROUP.

The Rock Springs coal group is the most important in this region and the one containing the highest-grade coal. Its lower portion consists of heavy beds of ridge-making, coal-bearing sandstone and the remainder of brown, yellow, and white sandstone, shale, clay, and interbedded coal. It contains at least twelve coal beds ranging from 2 to 10 feet in thickness and many other beds less than 2 feet thick. The total aggregate of coal beds over 2 feet thick in the Rock Springs coal group in the vicinity of Superior is more than 80 feet, and in the vicinity of Rock Springs it is more than 90 feet. These beds occur somewhat irregularly throughout the group, but are fairly persistent along the strike. They have been prospected all the way from Aspen Mountain northward to Rock Springs and Superior and on the east side of the dome to Black Butte Mountain. South of Superior the coal beds are somewhat thinner and the number of beds is not so great as between Superior and Rock Springs, and therefore very little prospecting has been done in that area. South of a line drawn through the southwest corner of T. 16 N., R. 104 W., and the southeast corner of T. 18 N., R. 102 W., the group is not known to be coal bearing. In part of this area the exposures are poor. Some coal beds may be present, but none were seen. The rocks here appear to be a continuation of the beds that were laid down under conditions similar to those which existed during the deposition of the "golden wall" in the northern and southern parts of the field. The coal is, however, of high grade and additional mines are certain to be opened in the near future at other points along the outcrop from Rock Springs to Aspen Mountain. Mines are in operation on upper beds of this coal group at Sweetwater, Rock Springs, and Superior. At Gunn and Van Dyke the coal beds near the base of the group (the Van Dyke coal beds) are being mined. New mines were to be opened in 1908 along Killpecker Valley, north of Rock Springs, but owing to the money stringency work was greatly delayed and some of it temporarily abandoned.

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[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 233, 234.

[b] Veatch, A. C., Bull. U. S. *Geol. Survey* No. 316, 1907, pp. 244-260.

The area underlain by the Rock Springs coal group was mapped in detail and the locations of mines, prospect pits, and the coal outcrops were determined by a stadia survey. The locations of the outcrops of the more important coal beds as well as the formation contacts are shown on Plate XV. The general character and thickness of the coal beds in the Rock Springs coal group are shown in the following sections taken at various points along the outcrop:

Sections of coal beds in the Rock Springs coal group in the southern part of the Rock Springs field, Wyoming.[a]

Location.				Section of coal bed.			Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*	Quarter.	Sec.	T.	R.		*Ft.*	*in.*
NE. ¼ NE. ¼.	14	17	105	Shale, brown	20		SE. ¼ SW. ¼.	14	17	105	Sandstone, white....	3	
				Coal........	3	8					Coal........	3	4
				Shale, brown		6					Shale, brown		6
				Sandstone, white......	10						Sandstone, white.		
					34	2						6	10

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[a] For sections of these beds in the northern part of the Rock Springs field see Bull. U. S. Geol. Survey *No. 341, 1909, p.* 262.

Sections of coal beds in the Rock Springs coal group in the southern part of the Rock Springs field, Wyoming—Continued

Location.				Section of coal bed.	Ft.	in.
Quarter.	Sec.	T.	R.			
SW. ¼ NW. ¼.	24	17	105	Shale, sandy Coal Shale, brown Sandstone, white 	6 3 1 8 18	 10 10
SW. ¼ SW. ¼.	1	18	105	Coal Shale Coal 	1 4 5	 ½ ½
SE. ¼ SE. ¼.	2	18	105	Shale. Coal Shale.	 7 	
SW. ¼ SE. ¼.	12	18	105	Shale. Coal Sandstone.	 5 	 5½
SW. ¼ SE. ¼.	22	18	105	Coal Shale Coal 	 4 4	10 ¼ 10¼
NW. ¼ NE. ¼.	34	18	105	Coal Shale Coal 	3 3	3 2 6 11
NW. ¼ NW. ¼.	25	19	105	Shale. Coal Sandstone.	 11 	
NE. ¼ NW. ¼.	25	19	105	Shale. Coal Shale.	 7 	
NE. ¼ NW. ¼.	25	19	105	Shale. Coal Shale Coal Sandstone. 	 2 1 5	 10 5 9
SW. ¼ SW. ¼.	26	19	105	Clay. Coal Shale, yellow Coal Shale, yellow Coal Shale, dark Coal Shale, yellow Coal Shale. 	 1 1 2 6	 6 1 4 3 2 1 9 1½ 2 5½
NW. ¼ SW. ¼.	26	19	105	Shale. Coal Bone Coal Shale. 	 1 1 4	 10 7 8 1
SW. ¼ SW. ¼.	26	19	105	Shale. Coal Shale.	 7 	 8
NW. ¼ SW. ¼.	30	19	105	Shale. Coal Sandstone.	 2 	 9
SE. ¼ NE. ¼.	30	19	105	Coal Shale, sandy Coal Shale. 	 1 3 5	6 10 4
NW. ¼ NE. ¼.	35	19	105	Shale. Coal Shale Coal Bone Coal Sandstone. 	 1 2 4 9	 3 8 4 6 11 8
NE. ¼ NE. ¼.	6	19	104	Coal Shale Coal 	1 3 5	8 3 8 7
NW. ¼ NE. ¼.	7	19	104	Coal Shale Coal 	1 1 2 4	6 6
SE. ¼ SW. ¼.	18	19	104	Coal Shale Coal 	3 2 3 8	 7 7
NW. ¼ SW. ¼.	5	20	104	Coal Shale Coal 	3 2 7 12	 8 8
SW. ¼ NW. ¼.	8	20	104	Coal Bone Coal 	5 1 1 7	1 3 4
SW. ¼ SE. ¼.	8	20	104	Coal	10	
SW. ¼ SW. ¼.	17	20	104	Coal Shale Coal 	1 3 5	3 3 6
SE. ¼ SE. ¼.	29	20	104	Coal Sandstone Coal 	5 3 8	 5 3 8
SE. ¼ SE. ¼.	30	20	104	Coal Bone Coal 	2 11 14	6 9 3

ALMOND COAL GROUP.

The Almond coal group is of second importance in the field. Its coals are not so good as those of the Rock Springs coal group and up to the present time have been little developed. The group consists of beds of carbonaceous shale, clay, and brown and gray sandstones, with numerous beds of coal in the lower half of the formation. Several coal beds from 2 to 8 feet thick have been prospected in various parts of the field. Unlike the Rock Springs coal group the Almond is known to be coal bearing around the entire dome. Mines were opened in these beds just east of Almond or Point of Rocks, in T. 20 N., R. 101 W., when the Union Pacific Railroad was first built. They were soon abandoned, however, and not reopened until the summer of 1907. The old No. 6 mine at Rock Springs (sec. 22, T. 19 N., R. 105 W.) was opened in these beds in 1882, operated for a short time, and abandoned in 1886, as the coal was found to be inferior to that obtained from the Rock Springs coal group. The aggregate of coal beds over 2 feet thick in the Almond coal group is from 15 to 30 feet and the beds occur chiefly in the lower half of the formation. The total thickness of the Almond coal group is exposed only on the east side of the dome. Throughout the remainder of the region the upper part is concealed by the overlap of the Black Rock coal group, and on the southwest flank of the dome the whole of the Almond coal group is covered by overlap of these same beds. In the area from T. 18 N., R. 105 W., to T. 14 N., R. 104 W., no exposures of the Almond coal group were seen. It is present, however, beneath the Black Rock beds and is believed to be coal bearing. The following sections, which are a few of the numerous measurements made at various points along the outcrop, show the character and thickness of these beds:

Sections of coal beds in the Almond coal group in the southern part of the Rock Springs field, Wyoming.[a]

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		Ft.	in.
SW. ¼ SW. ¼.	5	14	102	Shale.		
				Coal.......	7	11
				Shale.		
SW. ¼ SW. ¼.	6	14	102	Shale.		
				Coal.......	3	4
				Shale......	1	
				Coal.......	4	
				Shale.		
					8	4
NE. ¼ NE. ¼.	8	14	102	Shale.		
				Coal.......	7	
				Shale.		
SW. ¼ SW. ¼.	10	14	102	Shale.		
				Coal.......	3	6
				Shale.		
NW. ¼ NW. ¼.	13	14	103	Shale.		
				Coal.......	1	6
				Bone......	1	
				Coal.......	2	6
					5	

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[a] For sections of these beds in the northern part of the Rock Springs field see Bull. U. S. Geol. Survey No. 341, 1909, p. 263.

Sections of coal beds in the Almond coal group in the southern part of the Rock Springs field, Wyoming—Continued

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
NE. ¼ NE. ¼.	28	14	103	Shale.		
				Coal	1	9
				Shale	2	
				Coal	1	3
					5	
NE. ¼ NE. ¼.	30	14	103	Shale.		
				Coal	3	
				Shale	6	
				Coal	2	
					11	
SW. ¼ NW. ¼.	30	14	103	Shale	3	
				Coal	6	6
				Shale and sandstone	6	
				Coal	5	
					20	6
SE. ¼ NE. ¼.	25	14	104	Clay, sandy.		
				Coal	6	6
				Shale, brown.		
S. ½ SW. ¼.	31	15	101	Coal	3	4
				Shale	30	
				Coal	6	9
				Shale	5	
				Coal	1	8
				Shale	10	
					56	9
SW. ¼ SW. ¼.	4	15	102	Shale, brown	6	
				Coal	2	6
				Shale, brown	1	
				Sandstone, white.		
					9	6
NW. ¼ SW. ¼.	17	15	102	Shale, brown	15	
				Coal	4	
				Shale	1	6
					20	6
NW. ¼ NW. ¼.	28	15	102	Shale, brown	4	
				Coal	3	6
				Shale, brown.		
					7	6
SE. ¼ NW. ¼.	3	15	102	Shale, sandy	4	
				Coal	4	6
				Shale, brown	3	
				Sandstone	2	
				Coal	2	
					15	6
NW. ¼ NE. ¼.	10	16	102	Shale, brown	4	
				Coal	5	
				Shale, brown	2	
					11	
SW. ¼ SW. ¼.	33	16	102	Shale, brown	2	
				Coal	4	
				Shale, sandy		6
				Coal	4	
				Shale, brown	2	
					12	6
SE. ¼ SE. ¼.	8	17	101	Coal	4	10
SE. ¼ SE. ¼.	8	17	101	Coal	3	10
SE. ¼ SE. ¼.	8	17	101	Coal	4	10
NW. ¼ SW. ¼.	9	17	101	Coal	4	10
NW. ¼ SW. ¼.	9	17	101	Coal	3	10
NE. ¼ SW. ¼.	17	17	101	Coal	5	1
NE. ¼ SW. ¼.	17	17	101	Coal	3	8
SE. ¼ NW. ¼.	6	18	100	Shale.		
				Coal	3	
				Sandstone		1
				Coal	1	8
				Shale.		
					4	9
NE. ¼ NW. ¼.	6	18	100	Shale.		
				Coal	2	
				Shale	1	
				Coal	3	2
				Shale.		
					6	2
NW. ¼ NW. ¼.	10	18	100	Coal	2	4
				Coal, bony	1	3
					3	7
NE. ¼ SE. ¼.	10	19	105	Shale.		
				Coal	1	
				Clay		½
				Coal	4	
				Shale.		
					5	½
SE. ¼ NW. ¼.	14	19	105	Shale, drab.		
				Shale, carbonaceous	1	9
				Coal	1	6
				Shale, carbonaceous	2	
				Coal	1	
				Shale, carbonaceous	3	
				Coal	1	
					10	3

Sections of coal beds in the Almond coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
NE. ¼ SE. ¼.	22	19	105	Sandstone, yellow.		
				Shale	1	6
				Coal	1	2
				Bone		6
				Coal	2	1
				Shale	1	
				Coal	1	6
				Coal, bony		5
				Coal	1	11
				Shale		6
				Sandstone, yellow.		
					10	7
NW. ¼ SE. ¼.	1	20	105	Shale, brown	2	
				Coal	3	6
				Shale, brown.	3	
				Sandstone, brown	2	6
				Shale, brown	2	
				Coal	4	
				Shale, brown.	2	
					19	
NW. ¼ SE. ¼.	35	20	105	Shale.		
				Coal	4	
				Shale.		
NW. ¼ NE. ¼.	12	20	105	Shale	3	
				Coal	4	
				Shale and sandstone	7	6
				Coal	1	6
				Shale	2	
				Coal	2	6
				Shale	3	
					23	6
SW. ¼ NE. ¼.	13	20	105	Sandstone	2	
				Shale, brown	1	
				Coal	5	
				Shale, brown	6	
					14	
SE. ¼ SE. ¼.	24	20	105	Shale, brown	4	
				Coal	5	
				Shale, brown	2	
					11	
SE. ¼ SE. ¼.	25	20	105	Shale, brown	2	
				Coal	5	6
				Shale, brown	6	
					13	6

BLACK BUTTES COAL GROUP.

Along the east side of the dome the Black Buttes coal group, so far as known, lies conformably upon the marine Lewis shale. The basal member of the group consists of a massive bed of yellowish-white sandstone, in places over 100 feet thick, and is not known to be coal bearing. This member, resting upon the soft, friable Lewis shale, forms steep hills and cliffs along the contact. The rocks above it consist of variant sandstone, clay, and coal beds that lie exposed in the low hills and ridges east of the main scarp. The Black Buttes coal group is exposed only in the northern two-thirds of the east side of the dome and nowhere in the Rock Springs field does the entire group outcrop. The upper portion is concealed by overlap of the Black Rock coal group. In the southern part of the field, the Black Buttes coal group is exposed only for a distance of 12 miles southwest of Black Buttes. On the south and west sides of the dome this group is concealed and the Black Rock coal group rests unconformably in turn upon Lewis shale, the Almond coal group, and the white sandstone like that at Point of Rocks, lying between the Almond and Rock Springs coal groups, and at one place (in T. 15 N., R. 105 W.) upon the Rock Springs coal group. Considerable prospecting has been done at various places along this coal zone and good beds of coal are *exposed.* Near Black Buttes station the Union Pacific Railroad

Company opened a mine in 1868 which was worked for a time and then abandoned. The old Hall mine,[a] 2 miles south of Hallville station, after being worked a few years was abandoned, as the coal was not so good as that mined at Rock Springs. During the summer of 1907 a mine was opened in these beds 1½ miles southwest of Black Buttes station and coal from it was placed on the market in 1908.

The following sections taken along the outcrop illustrate the thickness and character of the coal beds in the Black Buttes coal group:

Sections of coal beds in the Black Buttes coal group in the southern part of the Rock Springs field, Wyoming.[b]

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
SW. ¼ SW. ¼.	1	17	101	Coal........	5	2
NE. ¼ NW. ¼.	12	17	101	Coal........	5	2
NE. ¼ NW. ¼.	14	17	101	Coal........	4	10
SE. ¼ SW. ¼.	14	17	101	Coal........	5	4
NE. ¼ NE. ¼.	22	17	101	Sandstone, brown....	12	
				Coal........	5	2
				Shale.		
					17	2
SE. ¼ NE. ¼.	23	17	101	Coal........	4	10
NE. ¼ SE. ¼.	4	18	100	Coal........	4	
				Bone.......		1
				Coal........	3	6
					7	7
NW. ¼ NW. ¼.	6	18	100	Coal.......	6	8
				Bone.......		½
				Coal.......	2	
					8	8½
SE. ¼ NE. ¼.	9	18	100	Coal.......	1	9
				Bone.......		3
				Coal.......		5
				Bone.......	2	
				Coal.......	5	1
					9	6
SE. ¼ NE. ¼.	9	18	100	Coal.......		5
SW. ¼ SW. ¼.	10	18	100	Shale........		4
				Coal.......		2
				Shale......		3
				Coal.......		2
				Shale......		3
				Coal.......		3
				Shale........	4	
				Coal.......	1	5
					6	10
SE. ¼ NW. ¼.	16	18	100	Shale.		
				Coal......	1	
				Sandstone and shale	15	
				Coal......	8	
					24	
NE. ¼ NE. ¼.	20	18	100	Shale and sandstone.		
				Coal......	6	6
				Shale and sandstone	78	
				Coal......	4	6
				Shale and sandstone	13	8
				Coal......	2	2
				Shale.		
					104	10
NE. ¼ NE. ¼.	20	18	100	Coal......	2	
				Shale.....		¼
				Coal......	3	6
				Shale.....		1
				Coal......		10
					6	5¼
NE. ¼ NE. ¼.	20	18	100	Coal......		6
				Bone......		½
				Coal......		4
				Shale.....		¼
				Coal......	3	5
				Bone......		½
				Coal......	1	1
					5	5¼
SW. ¼ NW. ¼	29	18	100	Shale.......		5
				Coal......	3	4
				Shale.......	7	10
				Coal......		3
				Shale.....		2
				Coal......		2
				Shale.......	9	
				Sandstone...	10	
				Coal......	5	8
					36	10

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[a] For a description of these mines see Bull. U. S. Geol. Survey No. 341, 1909, pp. 276-277.

[b] For sections of these beds in the northern part of the field see Bull. U. S. Geol. Survey No. 341, 1909, p. 264.

Sections of coal beds in the Black Buttes coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
SW. ¼ NE. ¼.	20	18	100	Shale.		
				Coal......	1	
				Shale.....		¼
				Coal......	4	2
				Shale.		
					5	2¼
NE. ¼ SE. ¼.	30	18	100	Shale.		
				Coal......	3	2
				Shale.....		¼
				Coal......	3	10
				Shale.....		6
				Coal......	1	8
				Shale.		
					9	2¼
SE. ¼ SE. ¼.	30	18	100	Shale.		
				Coal......	5	
				Shale.....		¼
				Coal......	1	10
				Shale.....		6
				Coal......	1	4
				Shale.		
					8	8¼
SW. ¼ SE. ¼.	30	18	100	Shale.		
				Coal......	3	4
				Shale.....		¼
				Coal......	4	
				Shale.....		5
				Coal......	1	10
				Shale.		
					9	7¼
SW. ¼ NE. ¼.	31	18	100	Coal......	6	8
NW. ¼ NE. ¼.	31	18	100	Shale.		
				Coal......	3	6
				Shale.....		¼
				Coal......	4	4
					7	10¼
NW. ¼ NE. ¼.	31	18	100	Shale.		
				Coal......	5	6
				Shale.....		¼
				Coal......	1	10
					7	4¼

KNOBS-CHEROKEE COAL GROUP.

In the eastern part of this region the Knobs-Cherokee coal group or "Upper Laramie" formation is separated from the "Laramie" formation by an unconformity. The base of the group consists of non coal-bearing beds composed of soft shale and brown conglomeratic sandstone, probably constituting the base of the Tertiary system. In other places this coal group is apparently conformable with the "Laramie." In part of the Great Divide Basin it is coal bearing in both the lower and upper portions. Coal beds in the Knobs-Cherokee coal group are present on the west side of the Rawlins dome and probably occur along the east side of the Rock Springs dome. They are, however, concealed by the overlap of the Black Rock coal beds. At best the location or even the presence of the base of these beds along the east side of the Rock Springs dome can only be inferred. For further information the reader is referred to Bulletin 341.[a]

At Cherokee Siding, in sec. 10, T. 20 N., R. 91 W., a prospect slope was driven down on a dip of 7° to a distance of 75 feet. At the old Fillmore station, in sec. 31, T. 21 N., R. 90 W., in an artesian well drilled by the Union Pacific Railroad Company, a 20-foot bed of coal was reported at a depth of 220 feet, a 10-foot bed at 270 feet, and a 15-foot bed at 320 feet. At Wamsutter, in sec. 34, T. 20 N., R. 94 W., several artesian wells were drilled by the Union Pacific Railroad Company to supply water for the railroad. In well No. 2 three beds passed through between 1,045 and 1,145 feet are considered as belonging to the same horizon as the four Cherokee coal beds described in T. 20 N., R. 91 W. The exact base of the Wasatch can not be determined from the Wamsutter well records, but from a careful consideration of the facts noted in the field and the relation of the coal beds that outcrop just north of Wamsutter and Latham it is believed that all the coal beds mentioned in the drill record below a depth of 150 feet belong to the Knobs-Cherokee coal group or "Upper Laramie" formation.

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[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 233-234.

Record of Union Pacific Railroad wells at Wamsutter.

WELL NO. 2.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	75	75	Strata, hard	3	528
Shale and small beds of coal	15	90	Shale, gray	32	560
Shale	5	95	Sandstone	20	580
Sandstone	15	110	Shale, gray	80	660
Shale, black and gray	40	150	Sandstone	20	680
Coal	5	155	Shale, black	35	715
Shale	65	220	Sandstone	15	730
Coal	5	225	Shale, black	5	735
Shale, gray	10	235	Sandstone, hard	5	740
Strata, hard	2	237	Shale	55	795
Shale	23	260	Sandstone, soft	35	830
Sandstone	25	285	Shale	102	932
Shale, gray and brown	195	480	Sandstone	28	960
Sandstone	15	495	Shale	85	1,045
Coal	5	500	Coal	7	1,052
Shale	25	525	Shale, black and gray	33	1,085

WELL NO. 3.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Soil or surface deposit	140	140	Rock, light gray	9	280
Sandstone, brown, very soft	20	160	Rock, very hard	2	282
Coal, small bed	5	165	Shale, light gray	58	340
Shale, light colored	35	200	Rock, dark brown	5	345
Sandstone, brown, very hard	1	201	Coal	5	350
Shale, light colored	14	215	Rock, dark brown	10	360
Chalk, cream colored, and soapstone	20	235	Shale, light gray, somewhat gritty	60	420
Coal	5	240	Rock, dark brown, hard and tough	15	435
Shale, light gray	18	258	Coal	15	450
Rock, hard	1	259	Sandstone, brown	35	485
Rock, soft, chalklike	11	270	Coal	5	490
Coal	1	271	Shale	235	725

The thickness of these beds at Wamsutter is probably 9,400 feet, and this is believed to be the entire thickness of the formation, as this place is very near the synclinal axis between the Rawlins and Rock Springs uplifts. For a description of sections along the outcrop of this formation illustrating the character and thickness of the coal beds, the reader is referred to the reports on the Great Divide Basin coal field [a] and the western part of the Little Snake River coal field.[b]

BLACK ROCK COAL GROUP.

The Black Rock coal group is thought to be of Fort Union age, but in this region the beds as a whole constitute the lowest member of the Wasatch formation, which here consists of three separate and distinct units. At the base of the coal group is a thin band of conglomerate, ranging in thickness from 2 to 6 feet near the central part of the dome and increasing in thickness northward. The pebbles are very small, consisting mostly of quartz, although in many places pebbles of other materials are present. This conglomerate marks an unconformable contact between this coal group and the Black Buttes coal group. Lithologically this coal group resembles the upper part of the Black Buttes coal group, but is on the whole whiter and more conglomeratic. The sandstone and shale, however, are more highly colored and more poorly cemented and contain a large number of spherical and irregular concretions. Slag due to the burning of coal beds was observed at several places in this field, but as a rule it is of very small extent compared with the material affected by the burning.

The Black Rock coal group consists of two members. The lower member is made up of light-gray sandy shale, with beds of much darker sandstone. The sandstone is medium grained, brown, and cross-bedded. Many of the beds of sandstone are concretionary and chip into small conchoidal fragments, resembling chert chips, and do not form pronounced ledges. The beds are rich in fossils and are the source of the best plant collections made in this field.

The lower portion of the upper member consists of massive brown sandstone interbedded with light and dark shales. The middle and upper portions of the member are predominantly shaly and have a rather decided greenish tinge. In the upper part of the member occurs a somewhat harder sandy shale which is one of the ledges of a well-marked scarp in this part of the field. In this ledge are found numerous plants which are pronounced by F. H. Knowlton to be of Fort Union age. Thin layers of sandstone with abundant gastropods are found in ledges of the scarp and a few feet below are several thin bands of low-grade bituminous coal.

According to the blueprints of the Union Pacific Railroad Company a well was drilled in these beds at Table Rock to a depth of 1,402 feet. The only record available states that the well was drilled in 1881 and gives the strata passed through to a depth of 550 feet. At a depth of 435 feet the record shows coal 15 feet thick. As no description of the beds at a greater depth than 550 feet is available, nothing further can be said regarding the coal beds that are supposed to occur in the Black Rock coal group in this part of the field. Wells were drilled by the Union Pacific Railroad Company at Red Desert, in sec. 6, T. 19 N., R. 95 W., and Bitter Creek, in sec. 10, T. 18 N., R. 99 W. The Red Desert well was drilled to a depth of 1,115 feet and Bitter Creek well to 696 feet. No coal was reported in either well; but at a depth of 546 feet in the Bitter Creek well the record gives 9 feet of rich petroleum shale. The wells were drilled by churn drills, and it is possible that the coal may have escaped notice or was not recorded in the logs. It does not seem probable that all the coal beds are thin or absent at so short a distance back from the outcrop on the east side of the Rock Springs dome.

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[a] Smith, E. E., Bull. U. S. Geol. Survey No. 341, 1909, pp. 233-234.

[b] Ball, M. W., Idem, pp. 252-253.

The lower half of the Black Rock coal group is richly coal bearing, some of the coal beds having a thickness of 25 feet. The coal beds on the east side of the dome lie nearly horizontal; those on the west side dip from 5° to 25° W. Not a few outcrops of coal beds in this group are concealed by a large amount of burned material. At various places throughout the field coal is burning along the outcrop at the present time. Coal for local ranch use is being mined at Hooten's prospect in sec. 24, T. 23 N., R. 104 W., and at the Menkinney mine in sec. 13, T. 15 N., R. 105 W., and to a less degree at some of the other prospects in this group.

The eastern boundary of this coal zone is described in the reports on the Great Divide Basin coal field, and the Little Snake River coal field already cited.[a] The same coal group spreads over a large territory in the southeastern part of the Rock Springs field, occupying a considerable area in the Vermilion Creek basin. Coals are known to outcrop in many parts of this basin in the southern part of Wyoming and the northern part of Colorado, but as this part of the field has not been mapped definite statements can not be made regarding them. Coal has been mined in a prospect on Canyon Creek, in sec. 7 or 8, T. 12 N., R. 101 W. The coal clearly belongs to the Black Rock coal group and its character is the same as that of the coal found in this group around the Rock Springs dome. E. E. Smith collected a sample of coal at this prospect, the analysis of which (No. 6795), is incorporated with those of the Black Rock coals in the table of analyses. The Black Rock coal group also extends southward across the state line into Colorado and lies exposed in the low synclinal trough between the south end of the Rock Springs dome and the north flank of the Uinta uplift. In a rapid trip across these beds from the end of the Rock Springs dome southwestward to Red Creek canyon it was observed that the Black Rock coal group extends southward, resting in T. 12 N., R. 105 W. on the white sandstone between the Almond and Rock Springs coal groups or on the Almond coal group.

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[a] Bull. U. S. Geol. Survey No. 341, 1909, pp. 220-242, 243-256.

The following representative sections taken along the outcrop of the coal beds at various places around the dome illustrate their thickness and character:

Sections of coal beds in the Black Rock coal group in the southern part of the Rock Springs field, Wyoming.[a]

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		Ft.	in.
NE. ¼ SW. ¼.	11	13	104	Coal.......	4	
SW. ¼ SW. ¼.	5	14	101	Shale, brown		
				Coal.......	9	
				Shale, brown.		
NE. ¼ NW. ¼	13	14	102	Coal.......	7	
NE. ¼ NW. ¼.	20	14	102	Sandstone...	6	
				Shale.......	1	6
				Coal.......	3	6
				Shale.		
					11	
SE. ¼ NE. ¼.	17	14	105	Coal.......	1	6
NW. ¼ NW. ¼.	22	14	105	Coal.......	3	
SW. ¼ NW. ¼.	21	15	102	Shale, brown	2	
				Coal.......	2	6
				Shale, brown	1	
				Sandstone, white.		
					5	6
NE. ¼ NE. ¼.	34	15	102	Shale, brown	2	
				Coal.......	2	6
				Shale, brown.		
					4	6
NW. ¼ SW. ¼.	13	15	105	Shale, blue.		
				Coal.......	2	6
				Clay... ..		1
				Coal.......	2	2
				Shale, black.		
					4	9
NE. ¼ SW. ¼.	1	16	102	Sandstone, brown.....	10	
				Shale, brown	3	
				Coal.......	9	6
				Shale, brown	1	6
				Sandstone, red.......	2	6
				Shale, brown	2	
				Coal, bony.	1	6
				Sandstone, brown ..	1	6
				Coal.......		8
				Shale, brown	15	
					47	2
NW. ¼ SE. ¼.	14	16	102	Sandstone, red.......	4	
				Shale, brown	6	
				Coal.......	7	6
				Shale, brown	2	
					19	6
NE. ¼ NW. ¼.	23	16	102	Sandstone, red........	2	
				Shale, brown	6	
				Coal.......	7	
				Shale, brown	2	
					17	
SW. ¼ NE. ¼.	24	16	102	Shale, sandy	6	
				Coal.......	2	6
				Shale, brown	3	
					11	6
NE. ¼ NE. ¼.	6	16	105	Coal.......		8
				Bone......		1
				Coal.......	2	
				Bone......		1
				Coal.......	1	
				Sandstone		2
				Coal.......		10
				Bone......		1
				Coal.......		9
					5	8
SW. ¼ NW. ¼.	6	16	105	Coal.......		10
				Bone......		1
				Coal.......		4
				Bone......		½
				Coal.......	3	1
					4	4½
SW. ¼ NE. ¼.	8	16	105	Coal.......	1	6
				Bone......		1
				Coal.......	2	
				Bone......		2
				Coal.......	1	1
					4	10
NW. ¼ SW. ¼.	16	16	105	Coal.......	1	8
				Bone......		1
				Coal.......	1	9
				Bone......		1½
				Coal.......	1	4
					4	11½
SE. ¼ SE. ¼.	17	16	105	Coal.......	1	1
				Bone......		½
				Coal.......		4
				Bone......		1
				Coal.......	1	2
				Bone......		½
				Coal.......	1	11
					4	8
NW. ¼ NW. ¼.	17	16	105	Coal.......	1	6
				Bone......		1
				Coal.......	2	7
					4	2

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[a] For sections of these beds in the northern part of the Rock Springs field see Bull. U. S. Geol. Survey No. 341, 1909, p. 265.

Sections of coal beds in the Black Rock coal group in the southern part of the Rock Springs field, Wyoming—Continued.

Location.				Section of coal bed.		
Quarter.	Sec.	T.	R.		*Ft.*	*in.*
SW. ¼ NE. ¼.	10	16	106	Coal.......	3	
SE. ¼ SE. ¼.	13	17	101	Shale. Coal....... Shale...... Coal........ Shale. 	 4 4	 4 6 10
SW. ¼ NE. ¼.	5	17	105	Coal....... Bone...... Coal....... 	 1 2	6 1 6 1
SW. ¼ NE. ¼.	29	17	105	Coal....... Bone...... Coal....... Bone...... Coal....... Sandstone Coal....... Bone...... Coal....... 	1 2 1 1 7	4 2 4 3 2 3 6 8 8
NE. ¼ SE. ¼.	30	17	105	Coal....... Bone...... Coal....... Sandstone. Coal....... 	1 2 1 4	2 1 3 2 1 9
SW. ¼ NW. ¼.	20	18	98	Coal....... Shale...... Coal....... Shale. 	 	4 4 3½ 11½
NE. ¼ SW. ¼.	29	18	98	Coal....... Shale...... Coal....... Shale. 	 1 1	4 4 8
NE. ¼ SW. ¼.	18	18	99	Shale. Coal....... Shale...... Coal....... Shale. 	 1 1 3	 4 4 6 2
SW. ¼ NW. ¼.	18	18	99	Shale. Coal....... Shale...... Coal....... Shale. 	 1 1 3	 4 2 6
SE. ¼ SE. ¼.	11	18	100	Shale........ Coal....... 	 2 2	3 6 9
SE. ¼ SW. ¼.	21	18	100	Shale........ Coal....... Shale...... Coal....... 	4 11 15	7 2 1 10
NW. ¼ NE. ¼.	23	18	100	Coal........ Shale....... Coal........ Shale......... 	1 2 1 4	 2 3 1 6
NE. ¼ NE. ¼.	31	18	100	Coal........ Shale....... Coal........ Shale....... Coal........ 	2 1 6 11	3 8 8 4 5 4
NW. ¼ NW. ¼.	34	18	100	Shale. Coal........ Bone......... Shale. 	 3 4	 6 6
NE. ¼ SE. ¼.	4	18	105	Coal........ Bone....... Coal........ Bone....... Coal........ Bone....... Coal........ 	2 3 1 8	7 1 8 2 8 2 1 5
SW. ¼ SE. ¼.	20	18	105	Coal........ Sandstone.. Coal........ 	2 2 4	 1 8 9
SE. ¼ SW. ¼.	21	18	105	Coal........ Bone....... Coal........ Sandstone.. Coal........ Bone....... Coal........ 	 2 5	10 1 9 2 8 1 8 3
NW. ¼ SW. ¼.	32	18	105	Coal........ Bone..-.... Coal........ 	 2 3	8 1 6 3
SW. ¼ SE. ¼.	10	19	105	Coal........ Bone....... Coal........ Bone....... Coal........ 	3 2 6	10 2 7 1 8
SE. ¼ SE. ¼.	13	23	104	Shale......... Coal........ 	2 7 9	 10 10
SE. ¼ NE. ¼.	24	23	104	Shale......... Coal........ Shale....... Coal........ Shale. 	5 8 14	 10 2

THE COAL.

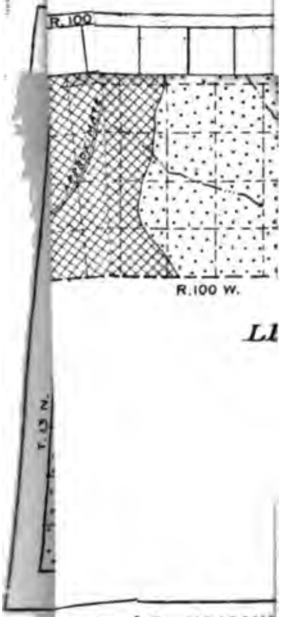
PHYSICAL PROPERTIES.

The Rock Springs coal is jet black as it comes from the mine, has a bright or even glassy luster, and in places shows iridescent colors. The structure of the bedding planes is as a rule well preserved, but jointing is not strongly developed. The coal is dense in texture and somewhat brittle. The streak ranges in color from brownish black to black. Many slickensided surfaces are present in this coal, as well as numerous faults. Considerable deposits of salts occur on the faces of the coal and on the sandstone along the entries in the mines. The coal on exposure to the air remains firm and compact and stands shipping without breaking down. On burning it produces no clinker and leaves a small bulk of red-white or reddish ash. Samples taken from surface prospects and placed in air-tight cans soon lose their bright luster and the surface becomes covered with a velvety-brown coating, which is probably due to the alteration of the weathered coal. The chief impurities of the coal are sulphur balls and small lenses of pyrite that are scattered somewhat irregularly through the bed.

The higher coals are also distinctly black, with a bright luster as they come from the mine. They show more traces of iron stain than the Rock Springs coal and contain considerable gypsum and salt flakes in the joints or bedding planes. On exposure to the air they alter more readily than the lower coals, lose their bright luster, and become a dull black. As they break down cracks form along and perpendicular to the bedding planes, producing somewhat regular blocks instead of the irregular pieces resulting from conchoidal fracture. These coals somewhat resemble the Adaville coal of Uinta County, but they seem to be affected less on exposure to the air and their fractures and joints are more regular and quite different from the conchoidal fracture of the Adaville coal.

CHEMICAL PROPERTIES.

On account of the slight amount of development work done in the southern part of the field it was not possible to obtain many representative samples of the coal for chemical analysis. Eleven samples were taken, but only one of these (No. 6672) was obtained from a fresh face of coal in an operating mine. Most of the samples were collected near weathered surfaces, from old abandoned prospects, and the coals were probably more or less altered. Most of the prospects from which samples were taken have been opened sufficiently to pass through the weathered zone near the surface, but deterioration in these places is in part due to the action of air on the walls of the coal in the prospect pit since the opening was made. Besides the eleven samples above mentioned, fifteen additional



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samples were collected to show the various stages of weathering or the depth to which weathering affects the chemical composition of the coal. Five samples were collected from the Rock Springs coal at the Gunn mine; five from the Almond coal at the mine east of Point of Rocks, and five from the Black Buttes coal southwest of Black Buttes. These are described in the next paper in this bulletin (pp. 282–296).

Representative samples of coal were collected from the four coal groups wherever good coal could be obtained and were sent in air-tight cans to the chemical laboratory of the fuel-testing plant at Pittsburg, Pa., for analysis.[a]

In order that the results from the samples collected might be entirely comparable, all sampling was done in accordance with the general plan adopted by the fuel-testing plant.[b]

The accompanying table gives the result of analysis of (1) samples as received in the laboratory, containing all the moisture that is present in the coal in the mine; (2) air-dried coal, after part of the moisture that is easily separated has been expelled; (3) dry coal, after the moisture has all been eliminated, and (4) pure coal, after the moisture and ash have been eliminated. The analyses are grouped according to the calorific values, the coal having the highest British thermal unit value in the air-dried sample heading the list for each of the four groups.

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[a] For analyses of coal sampled in the northern part of the Rock Springs field in 1907 see Bull U. S. Geol. Survey No. 341, 1909, pp. 270-273.

[b] Bull. U. S. Geol. Survey No. 341, 1909, pp. 12-13.

Analyses of coal samples from the Rock Springs coal field, Wyoming.

[F. M. Stanton, chemist in charge.]

ROCK SPRINGS COAL GROUP, LOWER PART OF MESAVERDE FORMATION.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6772	NW. ¼ NW. ¼	2	18	105	5′ 4″	5′ 4″	7.1	As received	11.5	36.8	50.1	1.62	0.75	5.94	68.29	1.16	22.24	6,791	12,224
								Air dried	4.7	39.7	53.9	1.74	.81	5.54	73.51	1.25	17.15	7,310	13,158
								Dry coal		41.6	56.6	1.83	.85	5.27	77.16	1.31	13.58	7,673	13,811
								Pure coal		42.4	57.6		.87	5.37	78.60	1.33	13.83	7,816	14,069
7091	NW. ¼ SE. ¼	8	19	104	5′ 10″	5′ 10″	12.4	As received	15.7	33.5	48.4	2.39	.93	6.11	63.11	1.30	26.16	6,191	11,144
								Air dried	3.8	38.2	55.3	2.73	1.06	5.40	72.04	1.48	17.29	7,069	12,721
								Dry coal		39.8	57.4	2.84	1.10	5.17	74.87	1.54	14.48	7,345	13,221
								Pure coal		40.9	59.1		1.13	5.32	77.06	1.58	14.91	7,559	13,606
7089	NW. ¼ SE. ¼	8	19	104	5′ 10″	5′ 10″	9.1	As received	13.5	34.9	49.4	2.24	.95	5.76	64.33	1.21	25.51	6,365	11,455
								Air dried	4.8	38.4	54.3	2.46	1.05	5.23	70.77	1.33	19.16	7,002	12,604
								Dry coal		40.3	57.1	2.59	1.10	4.93	74.31	1.40	15.67	7,352	13,234
								Pure coal		41.4	58.6		1.13	5.06	76.29	1.44	16.08	7,548	13,586
6796	NW. ¼ NW. ¼	24		105	3′ 6″	3′ 6″	9.2	As received	12.8	34.8	49.9	2.49	.76	5.84	64.78	1.30	24.83	6.312	11,362
								Air dried	4.0	38.3	55.0	2.74	.84	5.31	71.34	1.43	18.34	6,952	12,514
								Dry coal		39.9	57.2	2.85	.87	5.07	74.27	1.49	15.45	7,237	13,027
								Pure coal		41.1	58.9		.90	5.22	76.45	1.53	15.90	7,449	13,408
7092	NW. ¼ SE. ¼			104	5′ 10″	5′ 10″	11.5	As received	15.9	33.3	47.1	3.73	1.10	5.99	61.76	1.29	26.13	6,044	11,879
								Air dried	5.0	37.6	53.2	4.22	1.24	5.33	69.78	1.46	17.97	6,829	12,292
								Dry coal		39.5	56.1	4.44	1.31	5.02	73.44	1.53	14.26	7,187	12,937
								Pure coal		41.4	58.6		1.37	5.25	76.85	1.60	14.93	7,521	13,538
6799	NE. ¼ NE. ¼	14	17	105	3′ 6″	3′ 6″	8.3	As received	13.1	35.6	45.6	5.72	1.40	5.94	62.85	1.23	22.86	6,173	11,111
								Air dried	5.2	38.8	49.8	6.24	1.53	5.47	68.54	1.34	16.88	6,732	12,118
								Dry coal		40.9	52.5	6.58	1.61	5.16	72.32	1.42	12.91	7,103	12,785
								Pure coal		43.8	56.2		1.72	5.52	77.41	1.52	13.83	7,603	13,685
8534	NW. ¼ SE. ¼	8	19	104	5′ 10″	5′ 10″	9.4	As received	17.6	31.1	47.5	3.80	1.13	6.24	60.36	1.30	27.17	5,982	10,768
								Air dried	9.1	34.3	52.4	4.19	1.25	5.74	66.62	1.44	20.76	6,603	11,885
								Dry coal		37.7	57.7	4.61	1.37	5.19	73.26	1.58	13.99	7,260	13,068
								Pure coal		39.6	60.4		1.44	5.44	76.80	1.66	14.66	7,611	13,700

7090	NW. ¼ SE. ¼	8	19	104	5′ 10″	5′ 10″	17.3	As received....	23.3	31.9	41.5	3.27	.53	5.53	50.17	1.04	39.46	4,500	8,100
								Air dried......	7.2	38.6	50.2	3.95	.64	4.36	60.66	1.26	29.13	5,441	9,794
								Dry coal......	....	41.6	54.1	4.26	.69	3.83	65.41	1.36	24.45	5,867	10,561
								Pure coal......	....	43.5	56.5	....	.72	4.00	68.32	1.42	25.54	6,128	11,030
6791	SE. ¼ SW. ¼	14	17	105	4′ 0″	4′ 0″	18.4	As received....	24.2	32.1	40.0	3.70	.49	5.57	49.19	1.07	39.98	4,384	7,891
								Air dried......	7.1	39.4	49.0	4.54	.60	4.32	60.28	1.31	28.95	5,372	9,670
								Dry coal......	....	42.4	52.7	4.88	.64	3.80	64.90	1.41	24.37	5,784	10,411
								Pure coal......	....	44.6	55.4	....	.67	3.99	68.23	1.48	25.63	6,081	10,946

ALMOND COAL GROUP, UPPER PART OF MESAVERDE FORMATION.

7087	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	12.0	As received....	16.9	28.4	51.3	3.40	0.55	5.75	60.61	1.24	28.45	5 785	10,413
								Air dried......	5.6	32.2	58.3	3.86	.62	5.02	68.88	1.41	20.21	6 575	11,835
								Dry coal......	....	34.1	61.8	4.09	.66	4.66	72.96	1.49	16.14	6,963	12,533
								Pure coal......	....	35.6	64.4	....	.69	4.86	76.07	1.55	16.83	7,260	13,068
7102	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	13.6	As received....	18.8	29.5	48.2	3.52	.55	5.90	58.97	1.21	29.85	5,619	10,114
								Air dried......	6.0	34.1	55.8	4.07	.64	5.08	68.25	1.40	20.56	6,504	11,707
								Dry coal......	....	36.3	59.4	4.34	.68	4.69	72.65	1.49	16.15	6,923	12,461
								Pure coal......	....	37.9	62.1	....	.71	4.90	75.95	1.56	16.88	7,237	13,027
7094	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	12.4	As received....	17.9	29.5	49.3	3.27	.50	5.87	59.46	1.24	29.66	5,678	10,220
								Air dried......	6.3	33.7	56.3	3.73	.57	5.13	67.87	1.41	21.29	6,482	11,668
								Dry coal......	....	35.9	60.1	3.98	.61	4.73	72.44	1.51	16.73	6,918	12,452
								Pure coal......	....	37.4	62.6	....	.64	4.93	75.44	1.57	17.42	7,204	12,967
6773	NE. ¼ SE. ¼	22	19	105	8′ 4″	8′ 4″	9.1	As received....	14.9	32.9	47.8	4.42	.40	5.46	61.09	1.20	27.43	5,779	10,402
								Air dried......	6.4	36.2	52.5	4.86	.44	4.90	67.21	1.32	21.27	6,358	11,444
								Dry coal......	....	38.7	56.1	5.19	.47	4.47	71.79	1.41	16.67	6,791	12,224
								Pure coal......	....	40.8	59.2	....	.50	4.71	75.72	1.49	17.58	7,162	12,892
6797	NE. ¼ NE. ¼	25	14	104	6′ 6″	6′ 6″	15.0	As received....	18.6	29.7	48.1	3.55	.41	5.38	57.24	1.28	32.14	5,365	9,657
								Air dried......	4.3	34.9	56.6	4.18	.48	4.37	67.34	1.50	22.13	6,312	11,362
								Dry coal......	....	36.5	59.1	4.36	.50	4.07	70.33	1.57	19.17	6,592	11,866
								Pure coal......	....	38.2	61.8	....	.52	4.26	73.54	1.64	20.04	6,893	12,407
7095	SW. ¼ SW. ¼	26	20	101	7′ 2″	7′ 2″	8.6	As received....	14.0	31.1	50.8	4.09	.56	5.38	60.29	1.26	28.42	5,653	10,175
								Air dried......	5.9	34.0	55.6	4.48	.61	4.84	65.93	1.38	22.73	6,185	11,133
								Dry coal......	....	36.2	59.1	4.75	.65	4.45	70.07	1.46	18.62	6,570	11,826
								Pure coal......	....	38.0	62.0	....	.68	4.67	73.56	1.53	19.56	6,897	12,415
6775	NE. ¼ SE. ¼	10	19	105	4′ 6″	4′ 6″	13.7	As received....	21.0	31.3	40.1	7.60	.79	5.38	49.55	1.04	35.64	4,556	8,201
								Air dried......	8.5	36.3	46.4	8.81	.91	4.47	57.42	1.20	27.19	5,279	9,502
								Dry coal......	....	39.7	50.7	9.62	1.00	3.86	62.72	1.32	21.48	5,767	10,381
								Pure coal......	....	43.9	56.1	....	1.11	4.27	69.39	1.46	23.77	6,381	11,486
7088	SW. ¼ SW. ¼	26	20	101	6′ 4″	6′ 4″	7.5	As received....	14.3	33.2	47.1	5.44	.74	4.69	54.16	1.35	33.62	4,630	8,334
								Air dried......	7.3	35.9	50.9	5.88	.81	4.17	58.55	1.46	29.13	5,005	9,009
								Dry coal......	....	38.8	54.9	6.34	.87	3.63	63.17	1.57	24.42	5,400	9,720
								Pure coal......	....	41.4	58.6	....	.93	3.88	67.45	1.68	26.06	5,766	10,379

Analyses of coal samples from the Rock Springs coal field, Wyoming—Continued.

BLACK BUTTES COAL GROUP, "LARAMIE" FORMATION.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T.	R.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7093	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	15.6	As received....	20.8	28.4	47.1	3.73	0.36	5.98	57.11	1.06	31.76	5,507	9,913
								Air dried......	6.1	33.6	55.9	4.42	.43	5.03	67.66	1.26	21.20	6,526	11,747
								Dry coal.......	....	35.8	59.5	4.71	.45	4.63	72.08	1.34	16.79	6,950	12,510
								Pure coal......	....	37.6	62.4	....	.47	4.86	75.64	1.41	17.62	7,293	13,127
7097	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	13.1	As received....	18.7	29.2	48.4	3.73	.44	5.79	58.45	1.41	30.18	5,582	10,047
								Air dried......	6.4	33.7	55.6	4.29	.51	4.98	67.26	1.62	21.34	6,423	11,561
								Dry coal.......	....	35.9	59.5	4.59	.54	4.56	71.89	1.73	16.69	6,865	12,357
								Pure coal......	....	37.7	62.3	....	.57	4.78	75.34	1.81	17.50	7,195	12,951
7096	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	14.5	As received....	19.5	28.2	47.9	4.40	.37	5.89	57.34	1.40	30.60	5,465	9,837
								Air dried......	5.9	33.0	56.0	5.15	.43	5.01	67.07	1.64	20.70	6,392	11,506
								Dry coal.......	....	35.0	59.5	5.47	.46	4.62	71.27	1.74	16.44	6,792	12,226
								Pure coal......	....	37.1	62.9	....	.49	4.89	75.40	1.84	17.38	7,185	12,933
7170	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	7.9	As received....	18.9	28.9	48.1	4.13	.43	5.82	59.20	1.43	28.99	5,607	10,093
								Air dried......	11.9	31.4	52.2	4.48	.47	5.36	64.28	1.55	23.86	6,088	10,958
								Dry coal.......	....	35.7	59.2	5.09	.53	4.59	72.97	1.76	15.06	6,911	12,440
								Pure coal......	....	37.6	62.4	....	.56	4.84	76.88	1.85	15.87	7,281	13,106
7103	NE. ¼ NE. ¼	20	18	100	5′ 10½″	5′ 10½″	13.1	As received....	17.2	30.3	48.3	4.23	.35	5.36	56.22	1.51	32.33	5,216	9,389
								Air dried......	4.7	34.9	55.5	4.87	.40	4.49	64.69	1.74	23.81	6,002	10,804
								Dry coal.......	....	36.6	58.3	5.11	.42	4.17	67.91	1.82	20.57	6,301	11,342
								Pure coal......	....	38.6	61.4	....	.44	4.39	71.57	1.92	21.68	6,641	11,954

BLACK ROCK COAL GROUP, WASATCH FORMATION.

6794	NW. ¼ SW. ¼	13	15	105	4′ 8″	4′ 8″	4.5	As received	8.1	38.8	42.5	10.64	1.01	5.59	61.70	1.33	19.73	6,181	11,126
								Air dried	3.8	40.6	44.5	11.14	1.06	5.33	64.61	1.39	16.47	6,472	11,650
								Dry coal	....	42.2	46.2	11.58	1.10	5.10	67.12	1.45	13.65	6,724	12,103
								Pure coal	....	47.7	52.3	....	1.24	5.77	75.91	1.64	15.44	7,605	13,689
6774	SW. ¼ SE. ¼	10	19	105	6′ 8″	6′ 5″	8.4	As received	13.4	36.3	41.8	8.48	.83	5.90	59.84	1.15	23.80	5,813	10,463
								Air dried	5.4	39.6	45.7	9.26	.91	5.43	65.33	1.25	17.82	6,346	11,423
								Dry coal	....	41.9	48.3	9.79	.96	5.09	69.07	1.33	13.76	6,710	12,078
								Pure coal	....	46.4	53.6	....	1.06	5.64	76.57	1.47	15.26	7,438	13,353
6795	....	....	12	101	7′ 1″	6′ 9″	7.4	As received	12.4	39.2	36.9	11.53	5.44	5.42	55.78	1.54	20.29	5,626	10,127
								Air dried	5.4	42.3	39.8	12.45	5.88	4.97	60.24	1.66	14.80	6,076	10,937
								Dry coal	....	44.7	42.1	13.17	6.21	4.61	63.70	1.76	10.55	6,424	11,563
								Pure coal	....	51.5	48.5	....	7.15	5.31	73.36	2.03	12.15	7,399	13,318
6771	NE. ¼ SE. ¼	4	18	105	....	....	11.2	As received	19.8	35.7	37.8	6.70	.67	5.11	48.14	1.33	38.05	4,349	7,828
								As dried	9.7	40.2	42.6	7.54	.76	4.36	54.21	1.50	31.63	4,898	8,816
								Dry coal	....	44.5	47.1	8.36	.84	3.63	60.05	1.66	25.46	5,425	9,765
								Pure coal	....	48.6	51.4	....	.92	3.96	65.53	1.81	27.78	5,920	10,656

Samples of coal from the Rock Springs coal field, Wyoming.

Laboratory No.	Name of mine.	Sampling point.	Condition of sample.	Sampler.
6772	Wyoming Coal and Coke Co.	Second entry south. 20 feet north of fault.	Dry, unaltered	B. L. Johnson.
8534	Gunn-Quealy	1,100 feet from mouth	Dry, unaltered	H. E. Lewis.
7091	Gunn-Quealy	800 feet down slope	Dry, unaltered	J. L. Rich.
7089	Gunn-Quealy	80 feet down slope	Weathered	J. L. Rich.
6796	Millor	40 feet from entrance	Dry, unaltered	R. O. Bartholomew.
7092	Gunn-Quealy	150 feet from surface	Dry, unaltered	J. L. Rich.
6799	Kent	75 feet from opening, south entry.	Dry, unaltered	R. O. Bartholomew.
7090	Gunn-Quealy	10 feet down slope	Dry, badly weathered.	J. L. Rich.
6791	Kappes	40 feet from entrance	Slightly weathered	R. O. Bartholomew.
7087	Rock Springs-Wyoming Coal Co.	300 feet in from opening.	Dry, unaltered	B. L. Johnson.
7102	Rock Springs-Wyoming Coal Co.	1,000 feet in from opening.	Dry, unaltered	B. L. Johnson.
7094	Rock Springs-Wyoming Coal Co.	500 feet in from opening.	Dry, unaltered	B. L. Johnson.
6773	Old No. 6	300 feet west of opening.	Dry, weathered	B. L. Johnson.
6797	McCourt	30 feet from opening	Slightly weathered	J. L. Rich.
7095	Rock Springs-Wyoming Coal Co.	150 feet in from opening.	Dry, unaltered	B. L. Johnson.
6775	Prospect	100 feet down slope	Dry, unaltered	J. L. Rich.
7088	Rock Springs-Wyoming Coal Co.	50 feet from opening	Dry	B. L. Johnson.
7093	Rock Springs-Gibraltar Coal Co.	355 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7097	Rock Springs-Gibraltar Coal Co.	150 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7096	Rock Springs-Gibraltar Coal Co.	225 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7170	Rock Springs-Gibraltar Coal Co.	100 feet from opening down dip.	Dry, unaltered	B. L. Johnson.
7103	Rock Springs-Gibraltar Coal Co.	50 feet from opening down dip.	Weathered	B. L. Johnson.
6794	Menkinney	30 feet from opening	Dry, unaltered	A. R. Schultz.
6774	Interstate	54 feet west by 40 feet south of opening.	Dry, unaltered	B. L. Johnson.
6795	Canyon Creek prospect.	50 feet from opening	Slightly weathered	E. E. Smith.
6771	Prospect	50 feet from opening	Dry, slightly weathered.	B. L. Johnson.

BURNING OF OUTCROP.

In the western coal fields many coal beds have been burned along their outcrop, and in a few places the burning is going on at the present time. The extent of the burning is in general inversely proportional to the value of the coal.

In the Rock Springs field the amount of burning is relatively small in the Rock Springs and Almond coal groups and a little more prominent in each of the other coal groups, being most pronounced in the Black Rock. Considering the amount of burning that has been going on, the slag accumulations are small and unimportant, as the coal burns without leaving much clinker. In some places the effect on the adjacent rocks can be seen several feet from the actual seat of the burning; in other places rocks a very short distance away are not affected. The physical appearance of the coal bed near the burning or burned bed does not seem to be altered by the burning. On the other hand, the chemical analyses usually show decided differences between coal from the immediate vicinity of the burned or burning bed and similar coals collected from the same group at more remote distances. The coal taken near a burned area has become of considerably higher grade than the unaffected coal, having as a rule a higher British thermal unit value, lower air-drying loss, low volatile matter and high fixed carbon, and, in the ultimate analysis, high carbon and low hydrogen and oxygen. In this connection a comparison of analysis No. 5299 [a] with Nos. 5298, 5432, 5448, and 5447, representing the same group of coals, is interesting.

QUALITY OF COAL.

The lower coals of the Rock Springs coal group stand shipment well and do not slack on exposure to the air. They belong in the bituminous, noncoking class of coals. The coal of the Almond coal group is physically and chemically more closely related to the coals of the Black Buttes, Knobs-Cherokee, and Black Rock coal groups than to the Rock Springs coal. The chief difference is that all the coals above the Rock Springs coal group have more moisture and are lighter in weight than those of the Rock Springs and slack considerably on exposure to the air. These coals fall in the lowest grade of bituminous or the highest grade of subbituminous coals. As a rule they are better than the Adaville and Evanston coals of southern Uinta County. The coals of the Rock Springs field have a low sulphur content which ranges from 0.30 to 5.88 per cent, but is usually less than 1 per cent, averaging 0.84 per cent for the entire 85 samples collected. The coal beds in the four coal groups (Rock Springs, Almond, Black Buttes, and Black Rock) give comparatively clean coal and have a low content of ash, ranging from 1.51 to 17.41 per cent and averaging 5.43 per cent for the 85 samples collected.

The following table may be considered as representing the average condition of the coal in the five groups of coal beds. The table shows the relative values of these coals with respect to ash, sulphur, carbon, and fixed carbon. The Black Rock coals have the greatest amount of ash and sulphur, and in this respect as well as in their carbon content are only a little poorer than the Knobs-Cherokee coals. The Rock Springs and Black Buttes coals carry nearly the same amount of impurity and carbon.

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[a] Ball, M. W., Bull. U. S. Geol. Survey No. 341, 1909, p. 251.

Values of air-dried coal in the various coal groups in the Rock Springs coal field.

Coal group.	Number of samples.	Range.	Ash.	Sulphur.	Carbon.	Fixed carbon.
Black Rock	10	Maximum	17.41	5.88	65.33	52.78
		Minimum	4.94	.30	43.16	28.17
		Average	9.10	1.46	58.85	42.95
Knobs-Cherokee[a]	7	Maximum	10.51	1.18	09.12	58.68
		Minimum	1.70	.15	54.14	22.15
		Average	7.96	.80	59.11	41.18
Black Buttes	10	Maximum	5.15	.40	67.66	55.96
		Minimum	4.29	.64	62.52	47.94
		Average	4.58	.50	65.14	53.40
Almond	20	Maximum	11.74	.98	68.88	59.77
		Minimum	3.73	.32	52.94	41.97
		Average	6.27	.58	61.70	50.50
Rock Springs	45	Maximum	15.80	1.53	73.51	55.38
		Minimum	1.51	.36	44.75	34.98
		Average	4.41	.89	64.12	49.77

[a] Smith, E. E. The eastern part of the Great Divide Basin coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, p. 238. Ball, M. W., The western part of the Little Snake River coal field, Wyoming: Idem, p. 251. This coal group is not exposed in the Rock Springs dome, but is believed to be present.

As pointed out by David White,[a] ash and oxygen are of nearly equal weight as impurities in coal with respect to heat efficiencies. On arranging the values of the samples obtained in the Rock Springs field according to the ratio C ÷ (O + ash) it is found that these values have approximately the same order as the efficiencies determined calorimetrically. Although the order differs slightly from that of the British thermal unit values, the difference is small, the variation in thermal units being for the greater number of samples less than 100 and in few exceeding 500. Many of these samples were considerably weathered and it is remarkable that these ratios should correspond so closely with the determined British thermal unit values. From these analyses it appears that the ratio C ÷ (O + ash) furnishes a fairly satisfactory basis for grouping coals according to their heat efficiencies.

COMPARATIVE VALUES.

The coals of the Rock Springs coal group occur in the same geologic formation (the Mesaverde) as the bituminous coals of the Yampa, Danforth Hills, and Grand Hogback fields of Colorado and the Book Cliffs field of Utah, and compare favorably with those coals. They are not so good as the Kemmerer coals[b] (of Benton age) in Uinta County, Wyo., which show a tendency to coke and have a high heat efficiency.

Rock Springs coal bed No. 7 was tested by the United States fuel-testing plant at St. Louis in 1906 for producer-gas and coking properties.[c] Two mine samples and one car sample of coal were taken for chemical analysis. The analyses, together with the results of the producer-gas and coking tests, are given here for the purpose of comparison. Samples 3164 and 3165 were taken in the mine 5,200 and 7,000 feet north of the foot of the slope, and the coal bed at these places measured, respectively, 7 feet 6 inches and 7 feet 2 inches in thickness.

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[a] The effect of oxygen in coal: Bull. U. S. Geol. Survey No. 382, 1909.

[b] Schultz, A. R., Bull. U. S. Geol. Survey No. 316, 1907, pp. 219-222. Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 336-337.

[c] See "Wyoming No. 5," Bull. U. S. Geol. Survey No. 332, 1908, pp. 286-287.

Analyses of Rock Springs coal as received from bed No. 7, Rock Springs, Wyo.

	Mine samples.		Car sample.
Laboratory No.	3164	3165	3213
Air-drying loss	4.00	4.40	6.00
Proximate:			
Moisture	12.41	13.10	11.64
Volatile matter	36.57	34.97	36.37
Fixed carbon	48.50	48.59	48.58
Ash	2.52	3.34	3.41
Sulphur	.80	1.04	.81
Ultimate:			
Hydrogen			5.72
Carbon			66.08
Nitrogen			1.43
Oxygen			22.55
Calorific value (as received):			
Calories	6,622		6,538
British thermal units	11,920		11,768

Producer-gas test of Rock Springs coal (run-of-mine) from bed No. 7, Rock Springs.

COAL CONSUMED IN PRODUCER PER HORSEPOWER PER HOUR (POUNDS).

	Coal as fired.	Dry coal.	Combustible.
Per electrical horsepower:			
Commercially available	1.72	1.52	1.46
Developed at switchboard	1.60	1.42	1.38
Per brake horsepower:			
Commercially available	1.46	1.29	1.24
Developed at engine	1.36	1.21	1.16

ANALYSES.

COAL.		GAS.	
Moisture	11.44	Carbon dioxide (CO_2)	10.1
Volatile matter	36.37	Carbon monoxide (CO)	20.4
Fixed carbon	48.49	Hydrogen (H_2)	18.2
Ash	3.70	Methane (CH_4)	2.6
Sulphur	.91	Nitrogen (N_2)	48.3
		Ethylene (C_2H_4)	.4

Duration of test, fifty hours. Average electrical horsepower, 194.5. Average British thermal units per cubic foot of gas, 168. Total coal fired, 15,600 pounds.

Coking test of Rock Springs coal from bed No. 7, Rock Springs, Wyo.

Size as used: Raw, finely crushed. Duration of test, thirty-nine hours. Coal charged, 8,000 pounds. Coke produced, none. Analysis of coal: Moisture, 11.09; volatile matter, 34.53; fixed carbon, 50.50; ash, 3.88; sulphur, 0.84.

The Rock Springs coal as a locomotive fuel or steam coal has few superiors in the West. It burns under a forced draft without heavy sparking and is a quick steamer, leaving only a small quantity of ash. Although the coals of the Almond, Black Buttes, and Black Rocks coal groups have been mined and prospected very little in the past, the future no doubt will see extensive mining on all these coal beds. During the summers of 1907 and 1908 two mines were opened on coal beds of the Almond and Black Buttes groups and coal is now being shipped from them. The coal from these beds is no doubt much like the "Upper Laramie" coals of the Hanna field, and there is no apparent reason why it should not serve as well as most of the Carbon County, Sheridan (Wyo.), and Montana coals, which are at present extensively and satisfactorily used for firing locomotives on the Union Pacific and Burlington railroads. Although the coal is very light for such work, it has proved very successful when used under natural draft for heating purposes and a large trade in it has been developed.

HISTORY OF DEVELOPMENT.

PROSPECTING AND MINING.

Coal was discovered in Wyoming prior to 1834 on Belle Fourche River, but the first coal mine was opened at Coal Bank Hollow, near Rock Creek crossing, in Carbon County, where the Denver and Salt Lake stage company utilized the coal for fuel and blacksmithing purposes. Mining on a commercial scale, however, did not begin until the construction of the Union Pacific Railroad across Wyoming in 1867, 1868, and 1869. Prospecting for coal along the route of this road commenced in 1867, and coal was opened at Carbon, Point of Rocks, and Rock Springs early in 1868. The Carbon mines in 1868 produced the first Wyoming coal used by the railroad company. During August of that year the production amounted to 650 tons. A few months later the Rock Springs and Point of Rocks mines were ready for operation. The total coal production of Wyoming in 1868 was 6,925 short tons. The output for 1869 was as follows:

Coal production in Wyoming, 1869.[a]

	Tons.
Carbon	30,428
Rock Springs	16,903
Point of Rocks	5,426
Evanston (Almy)	4,439
Other localities	990
	58,186

The above figures are slightly different from those generally reported and given in the "Mineral resources of the United States"—49,382 tons. This discrepancy arises mainly from the fact that the product of the Point of Rocks mine and 2,473 tons mined by the Rocky Mountain Coal and Iron Company at Evanston are generally omitted from the reports. In forty-one years coal mining has developed into the leading industry in Wyoming, with an annual production of over 6,000,000 tons, valued at approximately $10,000,000, of which one-third comes from the Rock Springs field. The rapid construction of railways and the ever-increasing demand for fuel in this and adjoining States will make coal mining Wyoming's greatest enterprise for many years to come.

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[a] Raymond, R. W., Mineral resources west of the Rocky Mountains, 1872, pp. 370-371.

From the completion of the Union Pacific Railroad in 1869 to the construction of the Superior branch up Horsethief Canyon in 1906 all the mining camps in the Rock Springs field, except the Sweetwater camp south of Rock Springs, were opened along the railroad in Bitter Creek valley at distances of less than a mile from the main line. Although the entire Rock Springs field has been fairly well prospected, thus far only four districts—Rock Springs, Superior, Point of Rocks, and Black Buttes—are producing coal. All the mining camps within these four districts are less than 10 miles from the main line of the Union Pacific Railroad.

ROCK SPRINGS DISTRICT.

DESCRIPTION OF COAL BEDS AND OUTLINE OF DEVELOPMENT.

The Rock Springs district is by far the oldest, largest, and best developed in the field. It includes all the coal-bearing beds north and south of Bitter Creek valley on the west side of the dome in the vicinity of Rock Springs, or that part of Little Bitter Creek and Killpecker valleys whose source of supply and transportation centers about Rock Springs. Within this district have been opened seven mining camps—Rock Springs, Sweetwater, Blairtown, No. 6, Interstate, Van Dyke, and Gunn—most of which are still in active operation. In each of these camps, except the No. 6 and Interstate, there is one or more active operating mines at the present time. Of the four coal groups exposed in the Rock Springs dome, three (Rock Springs, Almond, and Black Rock) are exposed in the Rock Springs district. Mines have been opened on coal beds in each of these groups, but at present only the mines working on the coal beds in the Rock Springs coal group are in active operation. Several coal beds occur in the Black Rock and Almond coal groups in the Rock Springs district (see Pl. XIV), but thus far none of these beds have been profitably mined.

The total number of coal beds in the Rock Springs coal group has not been determined. Twenty beds that range in thickness from 2 to 12 feet are known; and it is certain that there are many beds less than 2 feet thick. One section taken across this group shows 37 distinct coal beds. That the number and thickness of the coal beds differ considerably at different points along the bed is equally certain. On being traced along the outcrop many of the larger beds are seen to become thinner and many of the thin beds to become thicker and workable. On the whole, the coal beds of this group are fairly persistent and regular. Of the large number of beds exposed in the hills on either side of Bitter Creek in the vicinity of Rock Springs, only five of the best have thus far been considered large enough to be worked.

Owing to the general practice of numbering mines according to the sequence in which they are opened by the company and later naming each coal bed after some prominent mine upon it, the designations of the Rock Springs coal beds, though in numerals, give no information regarding the stratigraphic order in which they occur.

All the mines in the Rock Springs district are located in Tps. 18 and 19 N., Rs. 104 and 105 W. The Sweetwater mine No. 1, in sec. 14, T. 18 N., R. 105 W., is the southernmost and the Gunn mine, in sec. 8, T. 19 N., R. 104 W., is the northernmost of the productive mines in this district. East-west lines drawn through the extreme north and south workings of these two mines would be only 7 miles apart. All the workings of the other mines in the district lie between these two, in a belt less than 5 miles wide. The five coal beds of the Rock Springs coal group on which mines have been opened in this district, together with their respective mines, are given in the following table in their proper stratigraphic sequence:

Stratigraphic position and thickness of five of the most important coal beds in the Rock Springs coal group and mines which have been opened on each bed.

Local name of coal bed.	Thickness. (feet).	Location of mouth of mine.				Name of mine.	Year opened.	Remarks.
		Quarter.	Sec.	T.	R.			
No. 5	6	SW. ¼ SW. ¼	26	19	105	Union Pacific Coal Co.'s old mine No. 5	1879	Abandoned 1885.
Interval	209							
No. 3	5-8	NW. ¼ SE. ¼	26	19	105	Union Pacific Coal Co.'s mine No. 3	1873	Worked out 1895.
		SW. ¼ SW. ¼	26	19	105	Union Pacific Coal Co.'s mine No. 5	1885	Abandoned 1890.
		NW. ¼ NW. ¼	8	18	105	Wyoming Coal and Coke Co.'s mine	1907	Operating.
Interval	224							
No. 1	7-12	NE. ¼ NE. ¼	35	19	105	Union Pacific Coal Co.'s mine No. 1	1868	Do.
		NW. ¼ SE. ¼	35	19	105	Union Pacific Coal Co.'s mine No. 2	1871	Abandoned 1883.
		NW. ¼ NW. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 4	1884	Worked out 1895.
		SW. ¼ NE. ¼	8	18	105	Rock Springs Coal Co.'s mine No. 1		Abandoned.
Interval	256							
No. 7	4-10	NE. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 7	1888	Operating.
		NW. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 8	1889	Do.
		NE. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 9	1890	Do.
		NW. ¼	25	19	105	Union Pacific Coal Co.'s mine No. 10	1900	Do.
		SW. ¼ NE. ¼	14	18	105	Central Coal and Coke Co.'s mine No. 1	1887	Do.
		NE. ¼ SW. ¼	36	19	105	Central Coal and Coke Co.'s mine No. 2	1889	Do.
			12	18	105	Central Coal and Coke Co.'s mine No. 3		Worked out 1907.
			2	18	105	Central Coal and Coke Co.'s mine No. 4		Do.
			11	18	105	Central Coal and Coke Co.'s mine No. 5	1907	Operating as part Central Coal and Coke Co.'s mine No. 1.
		SW. ¼ NW. ¼	1	18	105	Ludvigson mine		Abandoned.
Interval	207							
11, or Upper Van Dyke	2-6	NW. ¼ SE. ¼	8	19	104	Gunn-Quealy Coal Co.'s mine A	1907	Operating.
Interval	40-100							
Van Dyke	3-5	NW. ¼ SE. ¼	30	19	104	Van Dyke Coal Co. (now part of Central Coal and Coke Co.).	1870	Reopened 1887; closed 1895; reopened 1909.
		NW. ¼ SE. ¼	8	19	104	Gunn-Quealy Coal Co.'s mine B	1907	Operating.

That the five coal beds mentioned above are by no means the only ones in the Rock Springs coal group is best brought out by the following section, furnished to the writer by the Union Pacific Coal Company:

Section of the Rock Springs coal group in the Rock Springs district, showing the stratigraphic succession of the various coal beds as determined by the Union Pacific Coal Company.

Order of coal beds.	Local name of coal bed.	Distance from top of group to base of coal bed.		Section of beds.			Thickness of coal.		Distance from base of coal bed to base of next underlying coal bed.	
		Ft.	*in.*		*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
1	....	7		Shale	1		2	6	7	
				Coal, shaly	1					
				Clay	2	6				
				Coal	1					
				Clay	1					
				Coal		6				
2	....	30	3	Clay	2	6	1	9	23	3
				Shale	11	6				
				Sandstone	6					
				Coal, bony	1					
				Shale	1	6				
				Coal		9				
3	No. 5	67		Shale	3	9	7		36	9
				Sandstone	20					
				Coal	1					
				Clay	3					
				Coal	1					
				Shale	3					
				Clay and coal	5					
4	....	178	6	Sandstone	18		8	6	111	6
				Shale	2					
				Sandstone	69					
				Shale	5					
				Sandstone	9					
				Clay and coal	7					
				Coal, shaly	1	6				
5	....	217		Clay	7	6	13		38	6
				Sandstone	18					
				Clay and coal	13					
6	....	227		Sandstone	8		2		10	
				Clay and coal	2					
7	No. 3	248		Sandstone	6		13		21	
				Shale	2					
				Coal	7	6				
				Coal and clay	5	6				
8	....	265		Sandstone	6		2		17	
				Clay	4					
				Sandstone	5					
				Coal		10				
				Clay and coal	1	2				
9	....	278	6	Sandstone	4		1	6	13	6
				Shale	2					
				Sandstone	6					
				Clay and coal	1	6				
10	....	414		Sandstone	7	6	1		135	6
				Shale	7					
				Sandstone	12					
				Clay	11					
				Sandstone	97					
				Coal and clay	1					

Section of the Rock Springs coal group in the Rock Springs district, showing the stratigraphic succession of the various coal beds as determined by the Union Pacific Coal Company—Continued.

Order of coal beds.	Local name of coal bed.	Distance from top of group to base of coal bed.		Section of beds.			Thickness of coal.		Distance from base of coal bed to base of next underlying coal bed.	
		Ft.	*in.*		*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
11	No. 1	481	6	Shale	6		9	6	67	6
				Sandstone	12					
				Shale	18					
				Sandstone	17					
				Shale (fossils)	5					
				Coal	9	6				
12	....	577		Clay	1	6	2		95	6
				Sandstone	88					
				Shale	4					
				Coal	2					
13	....	605		Clay		6	1		28	
				Sandstone	9	6				
				Shale	17					
				Coal	1					
14	....	650		Clay		6	2		45	
				Shale	14	6				
				Sandstone	6					
				Shale (fossils)	22					
				Coal	1					
				Clay and coal	1					
15	....	689		Sandstone	6		1		39	
				Shale	7					
				Sandstone	3					
				Shale	4					
				Sandstone	6					
				Shale	12					
				Clay and coal	1					
16	....	713		Sandstone	22	6	1	6	24	
				Coal	1	6				
17	No. 7	743		Clay	3		7		30	
				Sandstone	6					
				Shale	4					
				Sandstone	5					
				Shale	3					
				Coal	1	6				
				Shale	2					
				Coal	5	6				
18	A	805	9	Clay	3		1	3	62	9
				Sandstone, white	58	6				
				Coal	1	3				
19	B C	825	9	Sandstone and shale	15	11	1	10	20	
				Coal		4				
				Shale	2	3				
				Coal	1	6				
20	D	855	10	Sandstone	27	2½	2	10½	30	1
				Coal	2	10½				
21	E	899	10½	Sandstone, white, and shale	38	9	3	10½	44	½
				Coal	1					
				Shale	1					
				Coal	2					
				Shale		5				
				Coal		10½				
22	F	915	6½	Sandstone, red, hard	12	9	2	11	15	8
				Coal	2	11				
23	G	932	½	Sandstone	16			6	16	6
				Coal		6				

Section of the Rock Springs coal group in the Rock Springs district, showing the stratigraphic succession of the various coal beds as determined by the Union Pacific Coal Company—Continued.

Order of coal beds.	Local name of coal bed.	Distance from top of group to base of coal bed.		Section of beds.			Thickness of coal.		Distance from base of coal bed to base of next underlying coal bed.	
		Ft.	*in.*		*Ft.*	*in.*	*Ft.*	*in.*	*Ft.*	*in.*
24	H or Upper Van Dyke	951	8½	Sandstone Coal	17 2	4 4	2	4	19	8
25	I	963	11	Shale Coal	10 1	7½ 7	1	7	12	2½
26	J	993	2	Sandstone, yellow Coal	28 	7 8		8	29	3
27	K	1,007	8	Sandstone, yellow Coal	12 2	 6	2	6	14	6
28	L	1,030	5	Sandstone, white Coal	20 2	9 	2		22	9
29	Van Dyke	1,055	9	Not recorded Coal Clay Coal	20 3	6 7 5 10	4	5	25	4
30	M	1,124	9	Not recorded Coal Shale Coal	66 1 	7 2 11 4	1	6	69	
31	N	1,133	9	Not recorded Coal	8 	8 4		4	9	
32	O	1,146	11	Not recorded Coal	12 	8 6		6	13	2
33	P	1,156	1	Not recorded Coal	9 	1 1		1	9	2
34	Q	1,180		Not recorded Coal Shale Coal Shale Coal	22 	6 2 3 2 5 5		9	23	11
35	R	1,211	4	Sandstone, yellow, and shale Coal	30 1	1 3	1	3	31	4
36	S	1,259	2	Sandstone, white Coal	47 	 10		10	47	10
37	T	1,275	8	Not recorded Coal	14 2	3 3	2	3	16	6
				Shale. Sandstone, massive, white; base of Rock Springs coal group.						
				Total coal			110	6		

Of the five coal beds thus far opened, Nos. 1 and 7 have produced by far the largest amount of coal, and nearly as many mines have been opened on No. 7 as on all the other beds together. On the Van Dyke bed two mines have been opened, one at Van Dyke and the other at Gunn. This bed as opened at the old Van Dyke workings averaged about 4 feet in thickness, and as a rule it is not less than 3 feet 8 inches nor more than 4 feet 2 inches thick. Overlying the Van Dyke bed is a group of beds which increase in size toward the north. About a mile north of the Van Dyke main entry there are openings upon three of these beds, two of them showing but 2 or 3 feet of coal, the third 4 feet 2 inches of very clean and bright coal. Still farther north, in sec. 8, T. 19 N., R. 104 W., on the western slope of Baxter Basin, two of the beds are at least 6 feet thick, a third about 4 feet, and several others smaller. In this section the Gunn-Quealy Coal Company opened its A and B mines, presumably on the lower and upper Van Dyke coal beds, respectively. Two of the larger coal beds have been opened about three-fourths of a mile farther north, where they are nearly 7 feet thick. These two beds are 40 feet apart and at least 200 feet lower than bed No. 7, which outcrops at the upper edge of the bluff forming the side of the basin.

Bed No. 7 has produced more coal than any other bed in the Rock Springs district, and, as shown by the description of the various camps, most of the producing mines are located on it. The coal bed shows considerable variation in thickness, but it is not over 10 feet thick in that part of the district opened by mine workings. It is, however, remarkable in maintaining a workable thickness of clean coal, and this more than counterbalances its small size.

The Central Coal and Coke Company's No. 1 mine is the most southerly large opening on this bed. It is situated in Sweetwater Valley and the main entry begins near the center of sec. 14, T. 18 N., R. 105 W. The bed here is from 7 feet to 7 feet 6 inches thick, is without partings, and has an average dip of 7° to 8° N. 85° W. A stratum of impure clay only a few inches thick lies immediately below the coal, and below that is a firm, massive gray sandstone. Above the coal there is 10 feet of clay shale, and above that a reddish sandstone that is also very persistent.

A mile northeast of the Central Coal and Coke Company's No. 1 mine there are a series of shallow cuts on bed No. 7 that show 7 feet or so of clear coal. About 2 feet from the roof there are two thin seams of clay, 2½ inches apart, each of which is from a quarter to half an inch thick. This double clay parting is uncommon, but a single parting of this character is generally present, the Central Coal and Coke Company's No. 1 mine being the only one that does not show it. The distance of this parting from the roof is about 2 feet, no matter what the thickness of the bed. Another peculiarity is the presence above the coal of a thin band consisting of alternate streaks of clayey matter and coal. This layer is from 2 to 5 inches thick, and when exposed to the air it soon scales down. Displacement along slips is well shown in one of the cuts referred to above. The two clay streaks show four small faults in a space of 20 inches.

The downthrow of these faults is (1) to south, 2 inches; (2) to south, 4 inches; (3) to north, 1 inch; (4) to south, 3½ inches. The inclination of the fault planes varies from 40° to 65° from the horizontal.

Along the outcrop of bed No. 7 toward Rock Springs the gray sandstone floor is in places very prominent and outcrops beyond the coal as a bare platform. Near the center of sec. 12, T. 18 N., R. 105 W. there are two faults approximately 700 feet apart. The movement of the block between these two faults was downward; the amount of displacement was not ascertained. Another displacement in bed No. 7 appears farther north, about 800 feet south of the west quarter corner of sec. 1, T. 18 N., R. 105 W. Here the bed is cut by a fault with a downthrow to the north of about 100 feet. This fault appears to have a general course of S. 60° W. and passes in this direction across the SE. ¼ sec. 2, T. 18 N., R. 105 W. Along the line of outcrop, not more than 1,400 feet north of the abovementioned corner, there is another fault with a displacement in the same direction probably amounting to 150 feet. This fault has a direction of about S. 75° W., and consequently diverges toward the west from the fault just described. It also passes into sec. 2. A peculiar feature of this fault is that it is lost to sight in the flat not far to the west, but along its general course, near the center of sec. 2, a fault is observed just north of the Klegg opening on bed No. 1, with an upthrow to the north of no great amount. Continuing on the same course, the fault is found to have a displacement of nearly 100 feet, with an upthrow to the north, as plainly shown on the outcrop of bed No. 3. The Wyoming Coal and Coke Company's mine, lying immediately north of this fault, shows no other serious displacement in that direction, and the continuous outcrop of the sandstone floor of bed No. 3 for some distance to the south indicates no disturbance in that direction. Consequently it appears either that the displacement shown on the outcrop of bed No. 7 makes a great change in its general course or that it rapidly decreases toward the west to a point where there is no displacement and then shows an increasing throw in the opposite direction. An apparent greater dip of the strata on the south side of this fault might perhaps help to explain the phenomenon. The same results might be obtained by a slight distortion of the block between the two faults.

In an opening on bed No. 7, known as the Ludvigson mine or prospect, between the two faults just described, the bed contains 6 feet of coal of excellent quality. The clay parting, 2 feet from the roof, is about a quarter of an inch thick.

The next opening toward the north on bed No. 7 is in sec. 36, T. 19 N., R. 105 W., where the Central Coal and Coke Company has opened its No. 2 mine. The bed, as exposed in the two strike entries, shows

5 feet of clear coal, broken only by the usual parting above mentioned. The dip is from 7° to 9°, but the strike has swung a little to the west (N. 10° to 20° E.). The roof and floor are of the usual character. The bed appears to have reached its minimum thickness of 4 feet 6 inches in this mine. The coal as a rule is very clean and pure. The normal clay parting is present. Near the eastern limit of the mine the streak of dirty coal and clay already referred to thickens and encroaches upon the upper bench of the coal. Other bands of carbonaceous clay appear lower down, but above the parting, and the entire upper 20 inches is worthless, in places leaving less than 3 feet of coal for mining. The poor coal is apparently confined to a narrow belt running in a northerly direction. Owing to the deep gulches in this section the outcrop is irregular and has never been accurately located. After crossing the main gulch near the center of the section it passes up a lateral ravine and, returning, swings in a bold curve across a high hill into the valley of Bitter Creek, on the north side of which the Union Pacific Coal Company's mines Nos. 7, 8, 9, and 10 are located.

North of Bitter Creek the Union Pacific Coal Company's mine No. 8 is a shaft about west of the No. 7 main entry. The coal appears to be of excellent quality in the workings and the bed is about 4 feet 8 inches thick.

North of mine No. 7, which extends nearly to the north end of T. 19 N., R. 105 W., several prospect entries have been excavated on the bed. Thus in the NW. ¼ sec. 20, T. 19 N., R. 104 W., an entry 175 feet in length shows the bed to contain about 8 feet of coal, as shown in the following section:

Section in entry in NW. ¼ sec. 20, T. 19 N., R. 104 W.

	Ft.	In.
Sandstone, hard, rusty.		
Shale, light, with siliceous band	9±	
Shale, dark	2	
Coal	2	4
Clay		⅓
Coal	3	1½
Shale, carbonaceous		5
Coal	2	
Clay, carbonaceous		6
Sandstone, massive, gray.		
Coal bed	7	10⅚

The coal is clear and bright and appears equal in every respect to that mined farther south. Another entry on the same bed starts near the top of the hills facing Baxter Basin in the SE. ¼ sec. 8 of the same township. Though the entry is over 200 feet in length it attains no great depth beneath the surface, and the coal shows the softening due to surface action in some of the streaks between the slips. The bed contains 7 feet 6 inches of coal. The clay parting is about 2 feet from the top. There is no carbonaceous shale near the bottom, as noted in sec. 20. The dip is about 10° and the strike has swung back to almost due north.

Bed No. 7, as well as many of the others, has been traced for several miles north, and prospects have been opened on it and other beds. (For locations see Pls. XIV and XV.) It can not be stated with certainty that the bed No. 7 at Rock Springs is the same as bed No. 7 at Superior, although the Superior beds were correlated and named from the Rock Springs coal beds. A comparison of the two sections of the Rock Springs coal group will show the relation between them.

Although the first coal mined at Rock Springs was taken from bed No. 1, the mines on it are closer together and less prospecting has been done along its outcrop than on bed No. 7, so that at present it is not so well understood. It is apparent, however, that although the coal in bed No. 1 attains a maximum thickness greater than that of bed No. 7 the former bed is by no means so regular as the latter and apparently contains neither the area nor the quantity of coal that bed No. 7 contains. The most southerly mine opened on bed No. 1 is the old Blair mine, sometimes known as the Rock Springs Coal Company's mine No. 1, at present owned in part by the Wyoming Coal and Coke Company. Next north is the now abandoned Union Pacific Coal Company's mine No. 2, then the Union Pacific Coal Company's Nos. 1 and 4, the latter being the most northerly on this bed. At present all these mines except the Wyoming Coal and Coke Company's mine and the Union Pacific Coal Company's mine No. 1 are abandoned.

South of the old Blair mine there are several openings. The Klegg entry to the southeast, directly south of the fault from Rock Springs Coal Company's mine No. 1, shows 10 feet of coal. Another opening on the east side of Sweetwater Valley shows 9 feet of coal and one to the west about 4 feet 6 inches. Bed No. 1 has been traced for miles northward from Rock Springs, but no extensive workings have been opened on it north of that city.

Bed No. 3 has been only a little developed. Three mines are located on it and show coal of good grade of from 6 feet to 7 feet 6 inches in thickness. Two of these mines have been abandoned and the third is just being opened.

Very little prospecting has been done, and only one mine has been opened on bed No. 5, consequently little can be said regarding it. At the place the mine was opened the coal was found to be slaty and the mine was therefore soon abandoned, but the indications along the outcrop suggest that this bed ought to furnish good coal in parts of the district.

ROCK SPRINGS CAMP.

The Rock Springs mining camp was the first one opened in the Rock Springs district. Several companies have operated here, and two are still active. Some of the mines, as the Blair mine and those of the Rock Springs, Excelsior, and Peacock coal companies, have shut down; others, as those of the Sweetwater Coal Mining Company, the Youngs mine, and the Klegg mine, have been consolidated with those of larger companies and are still producing. Mines in this camp have been opened on four beds of the Rock Springs coal group, Nos. 7, 1, 3, and 5. At present the only companies operating in the camp are the Union Pacific Coal Company and the Central Coal and Coke Company.

The Union Pacific Coal Company has opened mines Nos. 1, 2, 3, 4, old No. 5, 5, 7, 8, 9, and 10. Of these mines Nos. 7, 8, 9, and 10 were opened on bed No. 7; Nos. 1, 2, and 4 on bed No. 1; Nos. 3 and 5 on bed No. 3, and old No. 5 on bed No. 5. At present this company is working only beds Nos. 1 and 7. Mine No. 1 is working bed No. 1, and mines Nos. 7, 8, 9, and 10 are working bed No. 7. The Central Coal and Coke Company is working at present in this camp only bed No. 7, on which is located its No. 2 mine.

Union Pacific Coal Company's mine No. 1.—The Union Pacific Coal Company's mine No. 1 was opened in 1868 and is still producing. It is operated by a 7,500-foot double-track slope on the dip of the coal, which is about 5° at the outcrop, but steepens to 23° near the bottom of the slope. The direction of the dip and slope is a little north of west. Entries extend along the strike on either side, with rooms driven to the rise, parallel to the slope.

A peculiarity developed at many places in the workings of mine No. 1, but also common to the other mines on the same bed, consists of the so-called rock slips or horsebacks. These are long, slim wedges of white sandstone which protrude into the coal, usually from the floor. They have commonly a polished surface on one side and a rough surface to which the coal adheres on the other. Some of them extend only a few inches from the floor; others almost or quite to the roof of the bed. They are very narrow, being at most only a few feet wide at the base, and gradually wedge out. Longitudinally many of them extend for many yards. There appears to be no regularity in the direction in which they run or the frequency of their occurrence. The coal is of the normal quality, even where it is in direct contact with the pure sandstone.

The roof of this mine is usually shale and the floor brown or white sandstone. In all the lower entries 20 inches or 2 feet of coal is left for a roof. The section in this part of the mine is as follows:

Section of coal bed in mine No. 1 of the Union Pacific Coal Company at Rock Springs.

	Ft.	in.
Shale (roof).		
Coal (not mined in lower entries)	1	10
Coal, bony		9
Coal, good (mined and sampled)	7–8	
Sandstone (floor).		

A number of faults are present in this mine, which is in part bounded on the east and southeast by two faults, each with a maximum displacement between 65 and 70 feet and a downthrow toward the mine. These two faults probably intersect a short distance southeast of the mouth of the main slope. The one to the southeast separates the mine from the old Union Pacific mine No. 2, the other separates it from Union Pacific mine No. 4. The latter fault has been struck at several points, but the displacement has been determined at only one place, where it is 65 feet. Several other small faults and many slickensides are encountered in the eastern part of Union Pacific mine No. 1.

At a point nearly 3,500 feet from the mouth of the main slope a fault was encountered having an upthrow to the west of about 70 feet. Its general direction is northeast by north. The same fault in the main slope of mine No. 5 has a displacement of only 17 feet, and it seems to have died out farther to the northeast. In other words, the displacement of this fault decreases more than 50 feet in a horizontal distance of less than 1,000 feet. The coal bed contains 10 feet of clean coal west of this fault. The slope, which has an average inclination of 10° to 12°, was gradually flattened to half pitch and was so continued until the coal was again entered beyond the fault. There are a few minor faults and a considerable number of slickensides throughout the mine.

Union Pacific Coal Company's mine No. 2.—The Union Pacific Coal Company's mine No. 2, approximately half a mile south of the mouth of No. 1, was opened in 1871 on the same bed as No. 1, and operated until 1883, when it was abandoned because it contained too much water and on account of the numerous faults in this region. Faults of considerable magnitude bound this mine on the north and south. The fault between mines Nos. 1 and 2 has a general southwesterly direction and a maximum downthrow of about 70 feet toward the northeast. Approximately 30 acres of coal was mined. The bed contains some bone and dirty coal in the western and southwestern portions of the workings; however, as the lower entries in mine No. 1, less than a mile to the west, are driven more than half a mile farther south than the south end of mine No. 2, the bands of shale do not appear to interfere with mining and are not persistent.

Union Pacific Coal Company's mine No. 4.—Mine No. 4 lies to the northeast of No. 1. The slopes of the two mines are nearly a mile apart and opened on the same bed. The slope of No. 4, approximately half a mile northeast of mine No. 3, was driven parallel to the slope of No. 3 for a distance of 3,500 feet. Nine entries were turned off the slope on the south side and seven on the north. This mine was opened in 1884 and worked until 1895, when it was abandoned, as it ran into dirty coal on the north and all the good coal appeared to be worked out. The slope of No. 4 passes a little to the northeast of the true dip, which is locally about N. 65° W. Consequently the slopes of mines Nos. 1 and 4 diverge at a wide angle.

The coal bed in this mine contains two partings. The upper one is very persistent, though only 1 or 2 inches thick. It is a yellowish-white fine-grained argillaceous sandstone. The lower parting is the ordinary highly carbonaceous shale or so-called slate. It is not so persistent as the upper one, although present at many places. It disappears in the southwesterly workings and thickens toward the northeast. These partings are peculiar and well worthy of description. Below the burned zone which marks the outcrop, good coal is mined from both sides of the slope and shows only the yellow band about 2½ feet from the top. The lower levels ultimately strike bands of shale, at first a great distance from the slope, then nearer to it, until finally the shale shows in the face of the slope itself. The most prominent band is developed about 3 feet from the floor of the bed. Then other bands appear higher up and the yellow band changes to carbonaceous shale and thickens. Finally the lower band changes into sandstone and abruptly thickens by the raising of its upper surface until it replaces the entire upper portion of the bed. So rapidly is the change accomplished that the upper bench disappears within a distance of only a few yards beyond the point where the sandstone first begins. One entry that has been driven for 80 yards beyond this point shows 3 feet of coal on the bottom, continuing with great regularity, but with no sign of the upper portion of the bed; nor does a drill hole 8 feet deep show other than pure sandstone. At the face of the slope there is 2 feet of bony coal which has to be thrown out in mining, but the sandstone is not present. The entries to the south near the face of the slope pass out of this bony area within a short distance and the bed assumes its normal condition. In this direction all the development, both in this mine and in No. 1, tends to show that there is a very large area of excellent coal. Although the mine had a large supply of coal it was a one-sided mine below 2,500 feet from the surface—that is to say, all of the coal had to come from the southwest side of the mine below that depth on the slope. As soon as the southwesterly workings of the mine struck the fault that divides it from No. 1 and all the good coal was taken out the mine was abandoned.

Union Pacific Coal Company's mine No. 3.—The Union Pacific mine No. 3 was opened in 1873 and continued in operation until 1895, when it was abandoned because of a fire in the mine, which lasted for several years. It is reported that the mine was nearly worked out and for that reason was not reopened. The mine was opened on bed No. 3 and the slope was driven for a distance of about 4,000 feet N. 20° W., or a little northeast of the true dip. Twenty-four entries, twelve on each side, were turned off from the main slope and driven north and south for a distance of more than a mile. The face or breast of the mine extends for a distance of 2¼ miles, or from mine No. 5, with which it was connected, to the north end of sec. 23, T. 19 N., R. 105 W. Mine No. 3 exposes from 6 feet 6 inches to 7 feet 6 inches of clean homogeneous coal, and in the block of ground between slopes No. 3 and No. 5 the coal preserves the same character. The coal rests upon a bed of fire clay more than 1 foot thick, under which there is a bed of coal about 14 inches thick. Over the large bed there is first a clay shale, then sandstone. On the north side of the slope a band of shale appears about 2 feet from the floor of the coal. It changes to sandstone farther northeast and there only the bench above it is mined. In some places where the sandstone first appears the upper bench narrows to such an extent that rooms are not turned off, but 200 feet beyond this bench widens and affords from 4 feet 6 inches to 5 feet 6 inches of good coal. As in mine No. 4, this shale zone is far from the slope at the surface and rapidly approaches it with depth, so that it soon reaches the face. In other words, the edge of the bony area runs about halfway between the dip and the strike of the bed. The levels from a point near the face of the slope southwestward show 7 feet 6 inches of clean coal. The north entries strike a fault that seems to correspond to the one between mines Nos. 1 and 4. It has a displacement of 8 to 12 feet. Although its course is approximately north and south, it is very irregular. This indicates a dying out of the fault toward the north.

Union Pacific Coal Company's old mine No. 5.—Old mine No. 5 of the Union Pacific Coal Company was opened on bed No. 5 in 1879 and was abandoned in 1885, after approximately 20 acres of coal had been mined. The coal was mined through a slope from the surface. As soon as the mine was well opened it was learned that bed No. 5 contained too much shale to be of value and the mine was therefore abandoned. It is the only attempt made to open this bed in the Rock Springs field. A fault was encountered on the north side of this mine that is presumably the same as the one mentioned in the description of mine No. 5 below. The same fault is present in mine No. 1, which is on a bed 414 feet stratigraphically lower than bed No. 5.

Union Pacific Coal Company's mine No. 5.—The mouth of Union Pacific mine No. 5 is less than half a mile southwest of No. 3, with which it is connected, and is just east of the mouth of old mine No. 5. The mine was opened in 1885, operated until all the good coal was worked out, and then used as a part of No. 3 mine until 1890, when it was abandoned. There is but little to say regarding mine No. 5 that has not been covered in the description of mine No. 3. Both of these mines were opened on bed No. 3. Mine No. 5 was worked through a shaft, with a slope from the point where it struck coal bed No. 3. The slope was driven down the dip, approximately parallel to the slope of Union Pacific mine No. 1. The shaft of mine No. 5 is approximately 600 feet north and the face of the slope 900 feet north of the No. 1 slope. Twelve entries were turned off from the main slope, six toward the south and six toward the north. The north entries were driven only a short distance, as there is another area to the southwest of the mine in which a heavy band of shale appears near the center of the bed. This belt runs nearly at right angles to the stratum of sandstone near the bottom of the bed, as shown in the northerly workings of mine No. 3. A small fault cuts across the slope at the mouth of No. 5 entry. The strike is N. 80° E. and the block on the north side of the fault was moved upward about 6 feet.

Union Pacific Coal Company's mine No. 7.—Union Pacific mine No. 7 was opened in 1888 on coal bed No. 7 and was the first mine operated by this company on this bed. The mine was opened by means of a 1,300-foot entry driven on the strike. From this entry diagonal slopes run to the rise and entries are driven to each side. The entries have been pushed northward and northeastward for a distance of 4 to 5 miles, or nearly to the north township line. One entry extends into sec. 6, T. 19 N., R. 104 W. The entire underground workings of this mine are connected with mines Nos. 8, 9, and 10 in such a way that they are practically all part of one big mine, although they have separate slopes and entries. They are ventilated as if they were one mine and they are all made to drain to the pump of No. 10, which is the lowest on the dip. A fault was encountered near the north quarter corner of sec. 7, T. 19 N., R. 104 W. The bed south of the fault has moved up 12 feet. Several smaller faults and many slickensides were observed in the mine, but these do not interfere with mining.

Union Pacific Coal Company's mine No. 8.—Mine No. 8, which is connected with Nos. 7, 9, and 10, was opened in 1889 and is still in active operation. It is worked through a triple-compartment vertical shaft 180 feet deep. The coal is not screened or assorted. A single-track entry 14,000 feet long connects the lower ends of four single-track slopes with the shaft. Entries are driven on each side of the slopes and rooms are turned off parallel to the slopes.

The greatest pitch in the mine is about 7°, but varies from 5° to 7°. The coal near the shaft is 4 feet 6 inches thick, but farther down in the mine it is 7 or 8 feet thick and it averages from 7 feet 4 inches to 7 feet 7 inches. A layer of soft black shale 2 feet thick occurs just above the coal all through the mine. About 2 feet below the top of the coal bed, or approximately 5 feet 5 inches above the bottom, there is a thin shale parting which persists throughout the mine. It is in few places more than an inch thick. It keeps a uniform distance from the top of the coal bed, any increase in the thickness of the bed being added to the lower bench. The coal is very clean and needs no assorting after leaving the mine. Considerable pyrite was observed near the shale and the pyrite near the base of the coal occurs in little, thin plates. Below the coal bed there is 6 feet or more of brown shale containing in places a little coal. Below this is a sandstone layer. The roof of the mine is a bluish to chocolate-colored shale locally carrying fossils. Where fossils are present the roof is not so good as elsewhere. In mining, a thin layer of coal is left to form the roof, as it is better than the shale, which is liable to flake off.

The dip (5° to 7°) remains nearly constant throughout the mine. The strike, which is a little east of north at the shaft, gradually swings toward the west, till at the end of the mine it is a little west of north.

Union Pacific Coal Company's mine No. 9.—Union Pacific mine No. 9 was opened in 1890. The mouth of this mine lies 200 feet southeast of No. 7. It is the eastern part of the big mine formed by the connection of Nos. 9, 7, 8, and 10, which lie in the order named from east to west along the north side of Bitter Creek valley. This mine is worked very much like No. 8, except that the main entry is reached by an 800-foot slope instead of a vertical shaft. The main entry is 12,700 feet long, and the coal is brought to it through three slopes driven to the rise. The entries of No. 9 are not driven so far north as those of No. 7, which they parallel, but they have entered the S. ½ sec. 7, T. 19 N., R. 104 W. The method of work and operation is the same as in mines Nos. 7 and 8.

Union Pacific Coal Company's mine No. 10.—Mine No. 10 was opened by the Union Pacific Coal Company in 1900 and is still in active operation. It is the westernmost member of the big mine represented by Nos. 10, 9, 8, and 7, which produces nearly 1,500,000 tons of coal annually. The mouth of No. 10 mine lies approximately 600 feet west of No. 8 shaft. A rock slope with a grade of 15° reaches the coal at 1,200 feet and extends 1,500 feet in the coal at a 5° dip.

A fault was encountered in this mine near the mouth of the second entry. Its strike is a little east of north, but in going northward it swings toward the west, and where it cuts No. 3 and No. 4 entries the strike is nearly due north. Where the fault cuts No. 5 entry, 900 feet from the slope, it has a displacement of only 7 feet. An area of poor coal was encountered in the NW. ¼ sec. 24, T. 19 N., R. 105 W., as shown by openings in entries Nos. 4, 5, 6, and 7. The main slope ran into dirty coal and was abandoned. Entry No. 7 encountered this zone at 900 feet; entry No. 6 entered it 1,500 feet from the slope and was abandoned; entry No. 5 encountered the poor coal at several places 1,600 to 8,000 feet from the slope and is not worked at the present time.

Central Coal and Coke Company's mine No. 2.—The Central Coal and Coke Company's mine No. 2 was opened in 1888, on bed No. 7. The mouth of the mine lies about 1¼ miles south of the shaft of the Union Pacific Coal Company's mine No. 8. A slope is driven down the dip approximately 2,700 feet and entries are turned off toward the north and south. Most of the mine workings lie in the north and west halves of sec. 36, T. 19 N., R. 105 W.

In the southern part of the mine the coal is 6 feet 6 inches thick, in the northern part 4 feet 8 inches. On the north side a layer of bone from 4 to 8 inches thick is associated with the coal, but it pinches out before reaching the south side. Overlying the coal bed is 3 feet of shale, and on top of this is a 20-foot bed of gray sandstone. Twenty inches below the top of the coal bed is a shale parting three-eighths of an inch thick. A considerable number of slickensides and a few faults were observed in this mine. The largest fault lies in the SW. ¼ sec. 36, and cuts the entries approximately at right angles. Farther west the strike changes and the fault passes into sec. 35 with a trend a little south of west.

SWEETWATER CAMP.

The Sweetwater camp is the southernmost camp in the Rock Springs district. At present only the Central Coal and Coke Company is operating in this camp. This company is working bed No. 7, and has thus far worked four mines—Nos. 1, 3, 4, and 5. Mines Nos. 1, 3, and 4 were practically worked out in 1907. What little coal remains will be taken out through No. 5 slope. All these mines were combined in the fall of 1907 and are considered as part of the Central Coal and Coke Company's mine No. 1. The camp is reached by a spur built up Sweetwater Valley from Blairtown, on the Union Pacific main line.

Central Coal and Coke Company's No. 1 mine.—Mine No. 1 of this company was opened by Mark Hopkins in 1888 at Hopkinsville. Its mouth is a little northeast of the center of sec. 14, T. 18 N., R. 105 W.

Shortly after the mine was opened it was sold to the Sweetwater Coal Mining Company and the name of the village was changed from Hopkinsville to Sweetwater.

The coal in this mine is from 7 feet to 7 feet 6 inches thick, with neither bone nor parting. A stratum of impure clay only a few inches thick immediately underlies the coal and below this there is a firm, massive gray sandstone. Above the coal there is 10 feet of clay shale overlain by a reddish sandstone that is very persistent. The dip in the mine averages from 7° to 8° N. 85° W. A system of joints or slips commonly present in the Rock Springs coal is very prominent in this mine. In many places they part the coal from roof to floor every few feet. They are without doubt closely related genetically with the movements that produced the faults in the coal-bearing rocks. These slips run 5° to 20° south of the dip and are generally inclined toward the south. The faces present every peculiarity of faults, and along many of them there is an actual displacement of 1 to 4 inches. The fissures showing such a displacement usually pass into the roof of the bed, but where no displacement is observed this is not the case.

Central Coal and Coke Company's mine No. 3.—Mine No. 3 of the Central Coal and Coke Company lies in the NW. ¼ sec. 12, T. 18 N., R. 105 W. It is opened by a slope to the main entry, with slopes to the rise. This mine was nearly worked out in 1907 and has since been worked only in order to open mine No. 5, in sec. 11, north of the fault. The coal bed (No. 7) in mine No. 3 is about 5 feet 2½ inches thick[a] where it was sampled in slope entry No. 5, but runs from 4 to 8 feet in the mine. The clay parting is one-fourth inch thick and 7½ inches below the top of the coal. The coal is very similar to that mined by the same company in mine No. 4. Twenty feet above bed No. 7 lies another bed from 4 to 12 inches thick, but thus far no attention has been given to this upper bed.

At the back air course of entry No. 5 is a fault with a downthrow of 20 feet on the north side. South of the fault the coal is from 7 to 8 feet thick and north of the fault it is from 4 to 6 feet thick. Many slickensides and minor faults similar to those in mine No. 1 were noticed throughout the mine.

Central Coal and Coke Company's mine No. 4.—The Central Coal and Coke Company's mine No. 4 was nearly worked out in the fall of 1907. It lies north of No. 1 and west of No. 3, in the SE. ¼ SE. ¼ sec. 2, T. 18 N., R. 105 W. It was opened on bed No. 7 by a slope of 6½° about 1,700 feet long. A fault is present 1,300 feet below the mouth of the slope. The coal in this mine is 6 feet 3 inches to 7 feet thick, with a ½-inch shale parting 2 feet 3 inches below the top of the coal bed. The dip of the bed is about 5½° SW. and the strike about N. 5° W. On top of the coal bed lies an 8-foot layer of shale. This is hard, dark, and very fossiliferous. Above the shale is a gray sandstone; in places the dark shale is missing and this sandstone forms the roof of the coal. Below the coal is a massive bed of gray sandstone approximately 20 feet thick. No attempt is made to separate the shale parting from the coal. The mine is dry and only along the fault above mentioned was water observed. In the lower workings in the northwestern part of the mine a small spring was encountered near the fault. Many slickensides and minor faults occur in the mine, the conditions in this respect being very similar to those in mines Nos. 1 and 3. As measured on the parting the displacement ranges from a few tenths of an inch to several feet. The coal usually breaks along these walls or slips, and this breaking facilitates mining. The slickenside planes can be traced readily into the roof, but do not show displacement. Some sulphur balls are present in the coal, but most of the sulphur occurs near the base of the coal bed in the form of lenses. In addition some sulphur is disseminated through the coal.

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[a] In Bulletin 341, p. 270, the coal bed was erroneously reported to be 12 feet thick in this mine

Central Coal and Coke Company's mine No. 5.—The Central Coal and Coke Company's mine No. 5 was opened in 1907. It lies north and east of mine No. 1. A new slope was being driven in the fall of 1907. It was the intention of the manager, in order to shorten the haul, to combine all that was left of Nos. 1, 3, and 4 as soon as new entries were connected, about December 1, 1907. The coal in mine No. 5 in dip room No. 2 off back entry No. 5 is 7 feet 9¼ inches thick. No shale parting occurs in this bed northeast of the workings in mine No. 1. The roof is shale and the floor is gray sandstone, as in mines Nos. 3 and 4. At the fault along the north side of mine No. 1 and south of No. 5 the coal on the north side is 3 feet 3 inches thinner than on the south side of the fault, where it is nearly 8 feet thick. The downthrow amounts to about 20 feet on the north side.

The Central Coal and Coke Company's mines Nos. 1, 3, 4, and 5, although opened separately and spoken of as separate mines, constitute in fact one large mine, resembling in this regard the Union Pacific Coal Company's mines Nos. 7, 8, 9, and 10. All the mines are on bed No. 7, and the necessity of opening separate mines or changing the method of mining is due to the displacements caused by the numerous faults in this locality. As soon as mine No. 1 encountered the big fault on the north the entire workings had to be readjusted. Nearly all of the available coal in Nos. 1, 3, and 4 has been taken out. What remains of these mines and the new workings called "No. 5" are at present known as parts of Central Coal and Coke Company's No. 1 mine.

BLAIRTOWN CAMP.

The Blairtown camp lies about a mile south of Rock Springs, and has been the scene of coal mining for many years. The date of opening of this camp is usually given as 1869, although a few prospects were opened before that year. The Rock Springs Coal Company's mine No. 1, or the old Blair mine, was the first to begin operation and started in 1869. P. J. Quealy reopened this mine on bed No. 1 just north of the fault passing through the northern part of secs. 1 and 2. He also opened a small mine on the same bed south of the fault. These two mines lie south of the Union Pacific Coal Company's mines Nos. 1, 2, and 4 on the same bed, described under "Rock Springs camp." In May, 1907, another mine was opened on bed No. 3, a short distance west of the Rock Springs Coal Company's mine No. 1. Beds Nos. 1 and 3 are the only ones on which mines are operating in the Blairtown camp.

Rock Springs Coal Company's mine No. 1.—The Rock Springs Coal Company's mine No. 1 is situated in the NW. ¼ NW. ¼ sec. 2, T. 18 N., R. 105 W. It is said to have been first opened in 1869. Archibald Blair owned the property and opened the prospect as well as the mine. Work continued for a time and then the mine was shut down. Later the old Blair mine was leased to P. J. Quealy, who worked it for some time. Part of this mine, as well as the E. ½ sec. 2, became the property of the Rock Springs Coal Company, which reopened the mine in 1887 and produced 47,300 tons of coal in 1888. It was abandoned in 1903. The old Blair mine was opened on bed No. 1 just north of the fault above described. The original opening, known as the "Quealy mine or prospect," was opened on the same bed a few feet south of the fault by P. J. Quealy while operating the leased Blair mine. Both mines were worked by the Rock Springs Coal Company. The coal from the Quealy mine was run down an incline and loaded into cars at the Blair mine. When operations at the Blair mine were suspended the Quealy mine was also shut down.

In 1902 Matthew Muir reopened the Quealy mine by driving a new entry near the base of Quealy's workings, so as to save haulage. The new entry is a few rods west of the Quealy opening. The mine lies between two faults, one at the north, the other on the south, the distance between them being about 750 feet. The coal has been mined 1,200 feet down the dip. This property is at present owned by the Central Coal and Coke Company, and the mine is leased to Matthew Muir, who employs two miners. The coal is hauled to the mouth of the mine by horse, transported by wagon to Rock Springs, and sold locally or shipped with the Central Coal and Coke Company's coal. Practically all the coal taken out of this mine is used in Rock Springs for domestic purposes. Another opening, known as the "Young mine," was made in 1883 on the same bed a short distance to the north by George Young. The mine was worked for a short time by the Excelsior Coal Company and then abandoned because the coal was dirty and pinched out. The coal in the Blair mine is about 11 feet thick and in all the upper workings of the mine is perfectly clean. Bands of shale are encountered in the southwestern workings. They occur, however, near the base of the coal and 7 feet of clean coal lies above them. Union Pacific mine No. 2, now abandoned, also showed bony coal on this bed in the western and southwestern portions of its workings. It seems probable that there is here an area or zone containing bands of shale in this part of the bed and that both of these mines encountered it.

Wyoming Coal and Coke Company's mine.—In April, 1907, the Wyoming Coal and Coke Company opened a mine on bed No. 3 north of the fault described above as passing south of the old Blair mine. The south entries were worked only to the fault. Matthew Muir had previously opened a small mine on this bed a few rods south of the Wyoming opening and a few rods north of the fault contact. He leased the mine from Mr. Blair and worked it for a few years, until he encountered water. The new slope opened by the Wyoming Coal Company was driven down the dip of the coal bed, here about 12°. In September, 1909, the slope was down 1,600 feet. About 730 feet down a fault was encountered, which brings bed No. 1 up on the west into alignment with bed No. 3 east of the fault. Before striking bed No. 1 the slope passed through 90 feet of rock. Bed No. 3 was 4 feet 8 inches thick; bed No. 1 on the other side of the fault was 11 feet thick, mostly clean coal, with a few shale partings in the upper portion. In 1909 the company sunk a double-compartment shaft about 300 feet southeast of the mouth of No. 3 slope. The shaft was sunk 139 feet to a point where it struck bed No. 1. From the base of this shaft an entry was driven to the end of the old slope in Rock Springs Coal Company's mine No. 1, commonly known as the "Blair mine." The Wyoming Coal Company purchased the NW. ¼ sec. 2 from Mr. Blair and will extend and complete the workings of the old Blair mine as soon as the present entry connects with the Blair slope. In September, 1909, there was still 400 feet to open up. About 226 feet from the shaft, or 140 feet west of the end of the Blair slope, a small fault was encountered with the downthrow on the east. This is probably the same as the fault seen at the surface on the hill point just northeast of the mine, with a displacement of about 5 feet. A drill hole was sunk at the base of the shaft through bed No. 7, which was found to be 7 feet 6 inches thick. It is reported that the company intends to sink a shaft to bed No. 7, possibly to the Van Dyke bed, and to mine all these coals. The coal in bed No. 1 south of the old Blair slope is dirty throughout the lower part, having two or three shale partings nearly a foot thick. The upper 5 feet 6 inches is clean coal. West of the fault bed No. 1 is clean coal and has only a few partings in the upper part. Thus far most of the work has been confined to entries, which have been pushed forward as fast as possible, but little room work being done.

No. 6 CAMP.

No. 6 is the only camp on the west side of the Rock Springs dome where a mine has been opened on a coal bed in the Almond coal group. This camp was opened in 1882 by the Union Pacific Coal Company in sec. 22, T. 19 N., R. 105 W. The mine was known as the Union Pacific Coal Company's No. 6 and is often referred to as old No. 6 mine. The following section shows the condition of the coal bed:

Section of coal bed at old No. 6 mine.

	Ft.	in.
Sandstone, soft yellow.		
Shale	1	6
Coal	1	2
Bone		6
Coal	2	1
Shale	1	6
Coal	1	6
Coal, bony		5
Coal	1	11
Shale		6
Sandstone, soft, yellow.		
Total coal bed	9	1

Overlying the coal is about 18 inches of moderately soft chocolate-colored gypsiferous shale containing numerous fossils, apparently of the same species as those found at other points along the outcrop of the Almond coal group.

The mine was operated until 1886 and then abandoned, because the quality of the coal was such that it could not compete with the Rock Springs coal. A short prospect was opened on a 12-foot bed of coal west of and a little higher than bed No. 6, but no extensive work was done on it.

INTERSTATE CAMP.

The Interstate camp lies about 1½ miles north of No. 6 and is the only camp on the west side of the Rock Springs dome in this district where a mine has been opened in a coal bed belonging to the Black Rock coal group. This mine was opened in April, 1889, at the south center of sec. 10, T. 19 N., R. 105 W. Work was continued for a year and abandoned in 1890 on account of the poor quality of the coal, which could not be shipped without slacking. The small amount of coal that was mined was hauled to market in wagons or to the spur of the Union Pacific Railroad near old No. 6 mine. The coal is of about the same grade as that in No. 6 mine and would have no better market.

VAN DYKE CAMP.

The Van Dyke camp lies 2 miles east of Rock Springs and was the first camp where the lower coal beds of the Rock Springs coal group were mined. The Van Dyke mine, opened by Hall & Cotton in 1870, is located in the SW. ¼ sec. 30, T. 19 N., R. 104 W. The mine was soon abandoned, but was reopened by the Van Dyke Coal Company in 1888, when it produced approximately 20,280 tons.

The coal bed averages 4 feet in thickness. It shows little variation, being as a rule not less than 3 feet 8 inches nor more than 4 feet 2 inches thick. The roof of the bed is clay, which stands well so long as there is a current of dry air to carry away exuding moisture. Where it is not thus exposed it scales down in thick, heavy slabs. The floor is likewise clay, which is somewhat arenaceous a few feet below the coal. The dip of the bed where measured is from 3½° to 5° nearly due west. The coal is clean, showing no shale partings.

Between the Van Dyke mine and bed No. 7 on an east-west line there do not appear to be any beds of coal large enough to work, but there is a group of thin beds lying nearer the Van Dyke than bed No. 7, which increases in size toward the north. About a mile north of the Van Dyke main entry openings have been made on three of these beds, two of them showing only 2 or 3 feet of coal and the third 4 feet 2 inches of clean and bright-looking coal. Farther north, in sec. 8, T. 19 N., R. 104 W., on the western slope of Baxter Basin, the beds are thicker, so that two of them are at least 6 feet thick, a third about 4 feet, and several others smaller. In this section the Gunn-Quealy Coal Company opened its A and B mines, presumably on the lower and upper Van Dyke coal beds, respectively. Two of the larger coal beds have been opened about three-fourths of a mile farther north and are there nearly 7 feet thick. These beds are 40 feet apart and at least 200 feet lower than bed No. 7, which outcrops at the upper edge of the bluff forming the side of the basin.

The Van Dyke mine was again abandoned in 1895, as the thin coal did not yield enough to pay the expense of operation. Since then the property has passed to the Central Coal and Coke Company, which reopened the mine in the fall of 1909 and made preparations to extend the mine workings to much greater depths.

GUNN CAMP.

The Gunn camp lies in sec. 8, T. 19 N., R. 104 W., about 4½ miles northeast of Rock Springs, on the western edge of Baxter Basin. At this place P. J. Quealy and George Gunn, representatives of the Gunn-Quealy Coal Company, opened mines in order to develop the two beds which have been known throughout this district as the Van Dyke coal beds and which up to that time had been mined in a small way only in the Van Dyke camp, about 3 miles southwest of Gunn. In July, 1907, work was commenced on a spur from the Union Pacific main line near Baxter to the mine, and in September of the same year development of the mine was begun. The first shipment of coal was made in May, 1908.

The Van Dyke coal beds lie near the base of the Rock Springs coal group, and the lower bed, on which mine A is located, is probably the same bed as the Van Dyke, on which the Van Dyke mine was located. The mouths of the mines are about 4½ miles northeast of Rock Springs. Mine A is opened on the lower Van Dyke bed and mine B, 40 feet stratigraphically above mine A, is on the upper Van Dyke bed. Regarding the mines at the Gunn camp Superintendent H. E. Lewis makes the following statement:

> The coal pitches at this point about 9½° W. 8° S.; the upper bed averages a little more than 6 feet thick. The lower bed runs about 4 feet 9 inches thick, being thicker toward the north. The lower mine, or A, is 400 feet deep, with three entries turned off. The upper mine, or B, is 1,200 feet deep, with eight entries turned to the north and south. The upper mine, B, struck water level at the sixth level, or 900 feet below the surface, yielding about 200 gallons per twenty-four hours.

OTHER OPENINGS.

Many other prospects and entries have been opened on the Black Rock, Almond, and Rock Springs coal beds in the Rock Springs district. The most important are the Ludvigson mine, in the SW. ¼ NW. ¼ sec. 1, T. 18 N., R. 105 W., on bed No. 7, and the Carleson mine, in the SW. ¼ NW. ¼ sec. 6, T. 18 N., R. 104 W., on one of the coal beds near the base of the Rock Springs coal group. Very little coal has been taken from these mines, most of it coming from the entries. The Ludvigson mine was opened between two large faults and occupies the territory between the Central Coal and Coke Company's mine No. 2 at Rock Springs and the same company's mine No. 1 at Sweetwater. Most of the other openings were made primarily for prospecting purposes, with no intention of developing mines at those particular places.

POINT OF ROCKS DISTRICT.

The Point of Rocks district includes all the coal-bearing beds on the east side of the Rock Springs dome in the vicinity of Point of Rocks, or that part of the field north of Hallville, which is drained by Ninemile, Tenmile, and Twelvemile creeks—the area whose natural source of supply and transportation centers around Point of Rocks. Although this was one of the first districts to be opened in the Rock Springs field, very little mining has been done in it. Thus far only one camp, a mile east of Point of Rocks station, has been opened in the district. The Wyoming Coal and Mining Company, which had a contract to supply coal to the Union Pacific Railroad Company, opened a mine on a coal bed of the Almond coal group at this place as early as 1868. The main drift at this mine was driven northward at right angles to the dip of the beds, which is nearly due east. The mine was in operation until December, 1869, and was then abandoned, owing to the poor quality of the coal, as the same company was obtaining coal of a better grade at Rock Springs. The total production of the mine for that early period was 7,256 tons.

During the summer of 1907 the Rock Springs and Wyoming Coal Company reopened this mine and built a new spur from the main line to it, and in the latter part of the year began shipping coal. In the hill at this place five coal beds occur within a vertical distance of 80 feet. The lowest is approximately 100 feet above the bed of Bitter Creek. The new company opened two beds in 1907. The upper bed is 6 feet 4 inches thick and the lower 5 feet 1 inch thick. In 1908 the lower bed, which had been opened in 1868 and cleaned out in 1907 in preparation for new work, was abandoned owing to the large amount of impurities which make the coal inferior to that of the upper bed. The poor quality of this coal may be due in part to its weathered condition near the face of the old openings, as it is well known that coal of this type deteriorates rapidly when exposed to the air.

The upper bed varies slightly in thickness and was found to be 7 feet thick at the face of the mine in October, 1908. The yield of this mine in the fall of 1908 averaged 150 to 200 tons a day. There is a large amount of moisture in the coal, so that the company has considerable difficulty in disposing of the slack. At the mine the dip of the bed is about 6 per cent. The main entry, over 1,000 feet in length, is being driven on the level or in places with a little up grade in order to facilitate handling the loaded cars.

BLACK BUTTES DISTRICT.

The Black Buttes district lies on the east side of the Rock Springs dome and includes all the coal-bearing beds from the Point of Rocks district southward to Black Buttes Creek, or all the territory in this part of the Rock Springs field whose source of supply and transportation centers about Black Buttes station.

The district was opened in 1868, when the Union Pacific Railroad was built along Bitter Creek valley. Several mining camps have been established, but none of them are very extensive. The mines in one camp are operated on a coal bed near the base of the Black Rock coal group, and those in all the other camps on coal beds in the Black Buttes coal group.

BLACK BUTTES CAMP.

The first mine in the Black Buttes district was opened in 1868 in the hill east of Black Buttes station. It is commonly known as Morgan's mine and produced considerable coal. The coal, however, was inferior to the Rock Springs coal and the mine was soon abandoned. About 1890 it was reopened and continued in operation until 1893, producing about 50,000 tons. It was then again abandoned, presumably on account of poor markets for coal of that kind. The company worked an upper bed 4 feet thick and the main bed, 15 feet lower, 8 feet thick. The latter supplied most of the coal while the mine was in operation. In the summer of 1907 the mine was filled with water, so that no further investigation could be made.

During the days of the overland stage a small mine was opened just back of the stage station where coal was mined for local use. Another small mine, known as Maxwell's mine, was opened in the SE. ¼ NE. ¼ sec. 9, T. 18 N., R. 100 W., but was abandoned shortly afterward. Nothing further was learned regarding it.

In 1907 the Rock Springs-Gibraltar Coal Company opened a mine about 1 mile southwest of the old Black Buttes mine, on the same coal beds. The upper or principal bed is 6 feet 6 inches thick, and the other, 78 feet below, is 4 feet 6 inches thick. Another bed of good coal 2 feet 2 inches thick, which at present is not prospected, lies 13 feet 8 inches below the second bed. In working the coal the miners go in a short distance and then drift along parallel to the outcrop. A slope on the upper bed is opened down the dip to a depth of 300 feet. The output of this mine in the fall of 1908 was about 200 tons a day.

HALLVILLE CAMP.

The old Hall mine, about 4 miles northwest of Black Buttes station, on the west side of the railroad, was opened in 1868 on the same group of coal beds as those at Black Buttes. Regarding this mine Clarence King[a] makes the following statement:

> There are four seams of coal known to exist upon the claim. The upper one, 4 feet 8 inches in thickness, is near the surface and has never been developed, as the coal would be likely to prove of inferior quality. The second seam is 5½ feet in thickness, and has been worked to considerable extent, furnishing all the coal that has been sent to market from this mine. The third seam, 12 feet below the second and separated from it by a stratum of shale, is 9 feet 8 inches in thickness and promises to furnish a coal fully equal in quality to that taken from the one above. No work has been done upon it further than to prove its existence. The lower seam is not developed but is supposed to be about 3 feet in thickness.

This mine was situated just south of a large fault which carries the beds on the south side several miles toward the west. The mine was opened on a large fault block between Hallville and Black Buttes, and the beds are considerably distorted and irregular.[a] The mine was worked for a short time and then abandoned. At present only the ruins of the old camp remain.

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[a] U. S. Geol. Expl. 40th Par., vol. 3, 1870, p. 470.

In 1906 a mine was opened in a Black Rock coal bed east of the railroad, in sec. 28, T. 19 N., R. 100 W., by the Sioux City-Rock Springs Mining Company. This mine is south of a large fault which here, as well as at the old Hall mine, carries the beds on the south side several miles to the west. The company soon became involved in litigation, and all development work was abandoned. The mine was opened in a bed of coal 21 feet 10 inches thick by a slope driven down the dip to a depth of 300 feet. The first 100 feet was open-cut work, the remainder under cover. Along the slope about 8 feet of coal was removed, the rest of the bed being left in place.

OTHER DISTRICTS.

Many prospects and small local mines have been opened in various parts of the field (see Pls. XIV and XV) from which coal is taken in small quantities for local ranch use. These mines have not passed the prospect stage and will therefore not be considered at this time. There is no doubt that as future demands increase many new districts will be opened in the Rock Springs field, and that each district will contain several flourishing mining camps.

ECONOMIC CONSIDERATIONS.

MINING OPERATIONS.

Coal-mining operations in Sweetwater County have so far been conducted chiefly by two companies, the Union Pacific Coal Company and the Central Coal and Coke Company. At present the former operates almost wholly for the purpose of supplying coal to the Union Pacific Railroad. At Rock Springs the Central Coal and Coke Company has been mining coal for commercial markets since 1889. This company operates all the mines at Sweetwater and one mine at Rock Springs. The shipments of coal from other localities in this field have been meager and never exceeded a few hundred tons a day. Mines at present are being worked in the vicinity of Gunn, where the Gunn Mining Company is producing from 600 to 1,300 tons a day; at Point of Rocks, where the Rock Springs and Wyoming Coal Company is mining from 150 to 200 tons a day; and at Black Buttes, where the Rock Springs-Gibraltar Coal Company is mining about 200 tons a day. Outside of the Rock Springs and Black Buttes districts development has been confined to a slight amount of prospecting and to the opening of a few small mines from which to supply the local ranches.

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[a] See Bull. U. S. Geol. Survey No. 341, 1909, Pl. XIV, p. 258.

No doubt as future development work progresses most if not all of the mining in this field will be done by carrying slopes from the outcrop, much in the same way as at present. In places it may be found advantageous to sink shafts along the valleys some distance back from the outcrop where the overlying Tertiary beds have been removed. The room-and-pillar system prevails throughout the field. As a rule the pillars are not pulled at present. Mining is generally done by shooting off the solid face of the bed, but undercutting by hand and machine is employed in some of the mines. There is comparatively little gas, and accidents from this cause are relatively rare.

FUTURE DEVELOPMENT.

When new mines are to be opened in this field, whether in those districts where mines are already in active operation or in new districts far removed from any active mines or railroad stations, it will be necessary to consider carefully such factors as transportation, timber, and water supply, as well as the number, thickness, and persistence of coal beds, as all these items play important parts in the economic development of a new mine or district.

The most accessible routes for railroad transportation, and those of easiest grade, lie along the larger valleys or main drainage tributaries of Bitter Creek, namely, Little Bitter, Salt Wells, Black Buttes, and Killpecker creeks and their tributaries. Spur tracks built along any of these valleys will become feeders to the main line along Bitter Creek and afford an easy means of transportation, as gravity can be utilized in part in running the loaded coal cars from the mining camp or district to the nearest point on the main line.

In most of the mines thus far developed the roof and floor of the coal beds are firm and give little trouble in mining. It is necessary, however, to use timbers in parts of the mines. All props used in the mines must be shipped in, as there is very little timber in the region. Besides the few pines on Steamboat Mountain, in Pine Canyon, on Pine Buttes, and on Little Mountain, the only available timber is the juniper or scrub cedar used for posts, corrals, and fuel. The nearest sources of timber supply for mine use are (1) the Uinta National Forest, south of the field; (2) the Teton National Forest, in northern Uinta County, whence the timber could be floated down Hams Fork to Kemmerer or Granger and then shipped eastward by rail; (3) the mountain ranges on the east, including the Sierra Madre and the Ferris and Green Mountains; (4) the Wind River Mountains on the north, whence the timber could be hauled direct to the mines in the northern part of the field or could be floated down Green River and its tributaries to the town of Green River, and thence shipped eastward over the Union Pacific Railroad.

This entire region lies in the Red Desert of Wyoming. The only water available is that of Bitter Creek and a few small streams in the southwestern part of the field. The water of Bitter Creek is scanty in amount and not fit for domestic use. The few isolated springs that are scattered over the region are located for the most part along fault lines or along the contact of the lower shale of the Green River formation with the underlying formation. They furnish, as a rule, only a small quantity of water and can not be depended on to supply a mining camp. At Rock Springs water from Bitter Creek and water pumped from the mines is used to some extent for stock, but all water for domestic or household purposes is pumped from Green River. For the other mining camps in this district water for domestic purposes is shipped in large tanks by rail from Green River or Point of Rocks. In addition to the water shipped in, the water from small springs that rise along the faults in these localities is used by the miners at Superior and Point of Rocks, but this supply is not sufficient for a mining camp.

It appears, from well records and flowing wells at Rock Springs, Superior, Bitter Creek, and other points along the Union Pacific Railroad, that water can be obtained in almost any part of the Rock Springs field, outside of the Baxter Basin, which lies in the central part of the dome, by drilling to considerable depths. Whether the supply in all places will be large enough to meet the full demand of a mining camp or sufficient for irrigation or other agricultural needs can be determined only by careful and systematic drilling. In many parts of the field, particularly in the Great Divide Basin and other points along the east side of the dome, water may be obtained by drilling to relatively shallow depths, say several hundred feet. This water is likely to be highly alkaline and not good for domestic use.

MARKETS.

This field is situated about midway between the coal fields of Uinta County in southwestern Wyoming and those of Carbon County in south-central Wyoming. The coal from the Rock Springs field has about the same markets as that at present shipped from the Kemmerer and Hanna fields. Coal from these two fields has been carried eastward as far as Omaha, where it comes into competition with the coals of Iowa and Missouri; southward as far as Denver, where it is marketed with the Colorado coals; northward to the Black Hills, where it competes with the Sheridan and Cambria coals; and westward as far as the Pacific coast. During 1907 the demand of the western markets became so great that eastward shipments from Rock Springs were entirely abandoned and all the commercial coal produced was sent westward. So far as can be predicted the local market for the coal will be slight. Outside of Rock Springs and the villages and towns lying to the east and west along the Union Pacific Railroad and Oregon Short Line, with their various connecting lines and centers of industry, the use of the coal in this field will be confined to that needed by a few scattering ranches and in the development of the mineral resources of the surrounding mountains. No doubt a large part of the coal will be used by the railroad companies for fuel. Up to the present time only a small amount of the Rock Springs coal has found its way into commercial channels. Besides the present market furnished by the Union Pacific, Southern Pacific, and other western railroads using this coal for locomotive fuel, there is a ready market in many cities in the Rocky Mountain and Pacific States. The good quality of the coal and its nearness to the great smelting and sugar-refining industries in Salt Lake valley, Snake River valley, Anaconda, and Butte should command a good market. At present nearly all of the commercial Rock Springs coal goes west, the greater part of it to Salt Lake City, Utah.

AVAILABLE COAL.

In computing the amount of available coal in the southern part of the Rock Springs field, mapped in the summer of 1908 and discussed in this report, only those coal beds which are 2 feet 6 inches or more thick have been taken into consideration, although it is well known that bituminous coal beds 2 feet and less in thickness are being mined at present in Missouri, Arkansas, and many other States. The average thickness of the beds may be obtained from the representative sections given in the discussion of the four coal groups. It is assumed that the average thickness of the coal bed as computed from the measurements made along the outcrop will hold equally well for the bed down the dip. All the coal in the Rock Springs coal group belongs to the bituminous class and that of the Almond, Black Buttes, Knobs-Cherokee, and Black Rock coal groups to the low-grade bituminous and high-grade subbituminous classes. The specific gravity of these coals is about 1.3. A bed with a specific gravity of 1.3 and 1 foot thick contains about 1,132,500 short tons per square mile, or 1,770 short tons per acre. Using this factor in the calculation and taking all coal beds 2 feet 6 inches or more in thickness to a depth of 1,500 feet below the surface, or about 200 feet less than the deepest mine worked at present at Rock Springs, we obtain for the Rock Springs field the following gross tonnage:

Estimated gross tonnage of coal to a depth of 1,500 feet in the Rock Springs coal field, Wyoming.

[Short tons.]

Coal group.	Southern part of field.	Northern part of field.[a]	Total.
Rock Springs	3,032,100,000	4,843,000,000	7,875,100,000
Almond	3,818,200,000	3,110,783,000	6,928,983,000
Black Buttes	3,000,000,000	2,790,450,000	5,790,450,000
Knobs-Cherokee	2,000,000,000	6,000,000,000	8,000,000,000
Black Rock	8,590,950,000	35,576,640,000	44,167,590,000
	20,441,250,000	52,320,873,000	72,762,123,000

[a] Schultz, A. R., Bull. U. S. Geol. Survey No. 341, 1909, p. 282.

If the same factors are used but the computation is extended from the surface to a depth of 3,000 feet, or to the lowest limit of coal at present considered by the Geological Survey as workable, the estimated gross tonnage for these coal groups would be approximately twice that given in the above table.

It should be borne in mind that the amounts given above are merely estimates and that the total may vary from these figures by 25 to 50 per cent. The factors for computing the amount of coal present in the Knobs-Cherokee coal group are much more uncertain than those for the other groups, as it is not known where the base and top of these beds lie and how thick or numerous the coal beds are where they are under cover in the Rock Springs field. The tonnage given for this group is therefore merely a guess, based on what is known regarding the group west of the Rawlins dome and the general structural relations of the coal groups in the Rock Springs field.

WEATHERING OF COAL IN THE ARID REGION OF THE GREEN RIVER BASIN, SWEETWATER COUNTY, WYOMING.

By ALFRED R. SCHULTZ.

INTRODUCTION.

Coal beds in arid as well as in moist climates show considerable deterioration along the outcrop, and this deterioration in many places extends to the base of the belt of weathering or well down into it. The belt of weathering, from a geologist's point of view, is the surficial belt extending from the surface of the earth to the level of ground water. In this belt all the important reactions characteristic of the zone of katamorphism, namely, oxidation, carbonation, hydration, and solution, exert their maximum activity. The zone of katamorphism is the zone in which alterations of rocks result in the production of simple compounds from more complex ones. This zone extends from the surface of the earth to a depth of 10,000 meters,[a] and is divisible into two belts—an upper belt of weathering and a lower belt of cementation—the two being delimited by the level of ground water. As the ground-water level in arid regions lies at considerably greater depths below the surface than in well-watered regions, it is but natural to suppose that the belt of weathering extends to proportionately greater depths in dry than in moist climates. It would then follow that the deterioration of coal should extend farther below the surface in arid regions than in regions where the top of the water table lies only a few feet below the surface of the ground. That the deterioration of the coal does not always extend to the bottom of the belt of weathering, as above defined, or even to a considerable depth into this belt, is a fact not well known. In order to ascertain to what extent and depth the coal beds in the arid regions have been altered, some time was given to a study of the phenomena of weathering in the course of the geologic and stratigraphic investigation of the coal beds in the Rock Springs field, which range in age from lower Montana (Cretaceous) to Wasatch (Tertiary). A large number of coal samples were collected from beds both above and below the ground-water table, and show to what extent the coal has been altered. All samples except those taken from active operating mines came from a point in the bed above the top of the ground-water level. In the summer of 1907, when the northern half of the Rock Springs coal field was studied, 59 samples of coal were collected from various places in operating mines, abandoned prospects, and surface diggings. In 1908, when the southern half of the field was studied, 26 samples of coal were collected from various points, making a total of 85 samples collected and analyzed. Of these 45 were collected from coal beds in the Rock Springs group, 20 from coal beds in the Almond group, 10 from coal beds in the Black Buttes group, and 10 from coal beds in the Black Rock group.[a]

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[a] Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904, p. 160.

Considered with regard to physical as well as chemical properties, the coals occurring in these four groups fall into two classes—bituminous and subbituminous. The bituminous class includes all the high-grade coal of the Rock Springs group; the subbituminous class all the coal of the Almond, Black Buttes, and Black Rock groups. The difference between these two classes is physical as well as chemical. The Rock Springs coal usually has a lower percentage of water, remains firm and compact on exposure to air, and stands shipping well without breaking down. The coals from the three overlying groups, although from different horizons and of different ages, have essentially the same physical properties and bear a regional resemblance to one another. On exposure to the sun and open air they alter very rapidly, lose their bright luster, air slake, and break down into irregular blocks or powder. Cracks usually form along the bedding planes and somewhat irregularly in other directions. The coal does not stand shipping without breaking down or slaking, unless it is kept from the sun and circulating air while in transit. It may be stocked without slaking if kept from the sun and air. Chemical analyses of the samples taken from the coal beds of the four groups under approximately the same conditions seem to indicate that there is very little difference between the coals of the upper three groups, but that there is a marked difference between the coals of the two classes above mentioned when reduced to a pure-coal (moisture and ash free) basis. The unaltered Rock Springs coal averages approximately 600 British thermal units higher than the coals in the three overlying groups. It is probable that the former has undergone a more complete devolatilization, deoxygenation, and concentration, and does not assimilate oxygen so rapidly on exposure to the air as the other coals. The hydrocarbon compounds represented by the Rock Springs coal appear to be much more stable under atmospheric conditions than those represented by the higher coals.

Oxygenation, or weathering, along the outcrop of a coal bed manifested itself very strikingly as the examination progressed. Unlike the difference in physical characteristics, this alteration seems to be much the same in the two classes. It is clearly evident that along the outcrop of a coal bed and down the dip at least three zones may be recognized—those of surface weathering, underground weathering, and unaltered coal.

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[a] The stratigraphic relationship of these coal groups is explained on pp. 222-224.

ZONE OF SURFACE WEATHERING.

From work along the outcrop and samples collected from surface diggings and shallow prospects it is apparent that there is a belt of weathering near the surface in which all the coals are affected in much the same way. The good unaltered coal can not be reached until this weathered zone is removed. The chemical composition and the physical properties of the coal from this zone clearly show the altered and weathered condition. Samples taken from surface prospects and placed in air-tight cans soon lose their bright luster, the surface in some cases becoming covered with a velvety brown coating which no doubt is due to the alteration of the weathered coal. Evidence of the effects of exposure is seen in the H:O and VC:C ratios, as well as in the calorific deficiencies. Oxidation and decomposition in the belt of weathering soon alter the unstable chemical compounds of the coal so that it loses all traces of its original physical characteristics and the calorific values in an air-dried sample fall off one-fourth to one-half from those of the unweathered coal. Analysis of a sample taken from this belt of weathering affords an uncertain criterion for determining the value of the coal except in so far as it indicates the approximate amounts of sulphur and ash. The belt of surface weathering ranges in depth from 10 to 50 feet.

ZONE OF UNDERGROUND WEATHERING.

Besides the alteration observed in the belt of surface weathering similar phenomena were observed at much greater depths along the walls of more extensive prospects, slopes, entries, and rooms of mines, where the coal has been exposed to the air for a long period of time.

Oxygenation of the coal due to similar conditions was observed in many of the larger prospects, shallow mines, and drifts in the Rock Springs coal group. Many of these prospects were opened for 40, 100, or 150 feet and driven at the time of opening some distance back into unaltered coal, so that all of the deterioration now observed has occurred since their abandonment. Similar conditions were found in a shallow mine opened by Mr. Kappes in the SE. ¼ SW. ¼ sec. 14, T. 17 N., R. 105 W., and in the old Union Pacific mine No. 5 at Rock Springs. The same conditions were found in the three coal groups overlying the Rock Springs group. The chemical and physical results of weathering are not so apparent in these higher coals as in the Rock Springs coal, owing to the lack of large mines on the higher coal beds and to the smaller number of samples collected. Some of the best examples of these higher coals showing oxygenation as the result of exposure to air for a long time in mines of considerable depth come from the Rock Springs and Wyoming Coal Company's mine at Point of Rocks and from the old Union Pacific mine No. 6 at Rock Springs. Both of these mines were operated on beds in the Almond coal group and were worked for some time.[a] The same phenomena were observed in the old Black Buttes mine at Black Buttes,[b] opened on the Black Buttes beds and also on prospects driven into the unaltered coal to depths of 90 and 190 feet.

Oxygenation along the drift, prospect, and mine walls has not altered the coal so completely as in the belt of surface weathering. The coal along the faces of these underground openings where exposed to the air for a long period of time gradually assimilates oxygen, which it takes into combination, forming new hydrocarbon compounds from those present in the unstable equilibrium of normal coal as it lies in the coal bed. This assimilation of oxygen causes the coal to slake and its physical properties to change. On close examination it clearly shows deterioration; it has lost its bright luster and the smooth, firm surface of fresh coal and shows a decided calorific deficiency. Although the coal obtained from the faces of these old openings may seem firm and little altered, it seldom shows as good chemical results as samples obtained from working faces, and for this reason the analyses of many of the samples from deep prospects, old abandoned mines, and small country banks should not be taken as indicating the real merits of the coal. On the other hand, the analyses of such samples seldom show as poor results as those of coals taken from surface prospects or country banks in the belt of weathering. The following table shows the chemical composition of the Rock Springs coal in the three stages of weathering and the alteration of the coal from its nonweathered stage to its highly oxidized stage in the zone of surface weathering:

Summary of analyses of Rock Springs coal from zones of surface weathering, underground weathering, and unaltered coal.[c]

ZONE OF SURFACE WEATHERING.

Number of samples.		Moisture.		Volatile matter.			Fixed carbon.			Ash.		
		As received.	Air dried.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
7	Minimum	16.39	12.08	29.35	33.43	41.78	30.71	34.98	46.20	3.89	4.38	5.23
	Maximum	33.79	24.59	36.78	38.68	45.67	39.35	42.88	51.97	8.21	8.63	9.81
	Average	**26.40**	**19.68**	**32.31**	**35.90**	**43.91**	**36.18**	**40.20**	**49.18**	**5.10**	**5.65**	**6.91**

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[a] See Bull. U. S. Geol. Survey No. 341, 1909, pp. 276, 277; also p. 272 of this bulletin.

[b] See Bull. No. 341, p. 276.

[c] For complete analyses see Bull. U. S. Geol. Survey No. 341, 1909, pp. 270–272.

Summary of analyses of Rock Springs coal from zones of surface weathering, underground weathering, and unaltered coal—Continued.

ZONE OF SURFACE WEATHERING—Continued.

Number of samples.		Sulphur.			Hydrogen.			Carbon.			Nitrogen.		
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
7	Minimum.....	0.37	0.41	0.51	4.79	4.47	3.18	39.29	44.75	59.34	1.00	1.10	1.37
	Maximum.....	.95	1.00	1.14	5.86	5.22	3.97	50.09	52.95	63.20	1.26	1.39	1.75
	Average.......	**.65**	**.72**	**.87**	**5.55**	**4.93**	**3.58**	**45.65**	**50.12**	**61.80**	**1.17**	**1.28**	**1.59**

Number of samples.		Oxygen.			Calories.				British thermal units.			
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	Pure coal.	As received.	Air dried.	Dry coal.	Pure coal.
7	Minimum.....	34.72	31.97	24.11	3,356	3,822	5,068	5,588	6,042	6,884	9,122	10.057
	Maximum.....	46.90	41.07	26.06	4,511	4,800	5,730	6,046	8,120	8,640	10,314	10,883
	Average.......	**41.68**	**36.35**	**25.00**	**4,018**	**4,465**	**5,452**	**5,856**	**7,231**	**8,029**	**9,813**	**10,540**

ZONE OF UNDERGROUND WEATHERING.

Number of samples.		Moisture.		Volatile matter.			Fixed carbon.			Ash.		
		As received.	Air dried.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
11	Minimum.....	10.94	6.69	28.17	30.00	34.24	42.70	43.25	47.95	1.64	1.87	2.00
	Maximum.....	21.22	12.76	38.28	39.34	44.35	51.80	55.38	62.94	15.56	15.80	17.47
	Average.......	**15.43**	**10.16**	**33.17**	**35.25**	**39.39**	**47.02**	**50.02**	**55.52**	**4.37**	**4.56**	**5.08**

Number of samples.		Sulphur.			Hydrogen.			Carbon.			Nitrogen.		
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
11	Minimum.....	0.32	0.36	0.41	4.73	4.55	3.71	53.95	54.77	60.58	0.87	0.88	0.98
	Maximum.....	1.01	1.03	1.13	6.11	5.66	5.16	64.54	67.44	74.19	1.33	1.41	1.54
	Average.......	**.70**	**.74**	**.83**	**5.40**	**5.01**	**4.40**	**58.87**	**62.82**	**69.37**	**1.15**	**1.22**	**1.35**

Number of samples.		Oxygen.			Calories.				British thermal units.			
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	Pure coal.	As received.	Air dried.	Dry coal.	Pure coal.
11	Minimum.....	23.78	21.85	15.09	4,633	4,892	5,608	5,898	8,339	8,806	10,094	10,615
	Maximum.....	35.91	33.39	26.32	6,292	6,575	7,233	7,456	11,326	11,835	13,019	13,420
	Average.......	**29.04**	**25.14**	**18.48**	**5,449**	**5,793**	**6,445**	**6,795**	**9.809**	**10,430**	**11,601**	**12,212**

Summary of analyses of Rock Springs coal from zones of surface weathering, underground weathering, and unaltered coal—Continued.

ZONE OF UNALTERED COAL.

Number of samples.		Moisture.		Volatile matter.			Fixed carbon.			Ash.		
		As received.	Air dried.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
18	Minimum.....	8.53	6.04	31.52	33.35	36.15	47.10	49.16	53.83	1.44	1.51	1.67
	Maximum.....	14.63	10.85	36.41	37.94	40.66	52.61	54.43	59.07	9.04	9.30	10.02
	Average.......	**11.60**	**8.10**	**34.02**	**35.60**	**38.74**	**49.78**	**52.08**	**56.67**	**4.02**	**4.21**	**4.58**

Number of samples.		Sulphur.			Hydrogen.			Carbon.			Nitrogen.		
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.
18	Minimum.....	0.72	0.77	0.82	5.36	5.14	4.59	61.47	64.16	70.66	1.09	1.15	1.24
	Maximum.....	1.46	1.52	1.69	6.05	5.79	5.25	68.98	71.85	77.04	1.49	1.57	1.66
	Average.......	**.97**	**1.02**	**1.10**	**5.71**	**5.46**	**4.97**	**65.33**	**68.45**	**75.00**	**1.22**	**1.28**	**1.39**

Number of samples.		Oxygen.			Calories.				British thermal units.			
		As received.	Air dried.	Dry coal.	As received.	Air dried.	Dry coal.	Pure coal.	As received.	Air dried.	Dry coal.	Pure coal.
18	Minimum.....	19.66	16.59	12 16	6,086	6,353	6,959	7,571	10,955	11,435	12,526	13,627
	Maximum.....	25.82	22.88	15.85	6,868	7,101	7,613	7,929	12,362	12,782	13,738	14,272
	Average.......	**22.71**	**19.64**	**13.65**	**6,479**	**6,784**	**7,308**	**7,726**	**11,662**	**12,206**	**13,272**	**13,908**

The above table shows the range and the average chemical composition of the samples of Rock Springs coal obtained in 1907. The following table gives the average of all analyses of samples of each group of coals obtained in the Rock Springs field in 1907–8 and is here given for the purpose of comparison:

Average of the analyses of air-dried samples of coal from the Rock Springs field, Sweet water County, Wyo.

ZONE OF SURFACE WEATHERING.

Coal group.	Number of samples.	Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.		British thermal units in pure coal.
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
Black Rock...	2	10.55	20.41	34.05	30.93	14.65	1.17	4.50	43.16	0.92	38.23	3,602	6,484	9,997
Almond......	6	6 80	14.66	32.98	44.89	7.46	.48	4.74	53.77	1.26	34.21	4,840	8,622	10,885
Rock Springs.	8	10.92	16.88	36.24	41.45	5.43	.71	4.85	51.63	1.28	35.32	4,587	8,250	10,602

Average of the analyses of air-dried samples of coal from the Rock Springs field, Sweetwater County, Wyo.—Continued.

ZONE OF UNDERGROUND WEATHERING.

Coal group.	Number of samples.	Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.		British thermal units in pure coal.
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
Black Rock...	2	11.85	10.37	37.99	45.19	6.44	0.84	4.61	57.05	1.28	30.24	5,231	9,420	11,314
Black Buttes..	5	6.90	9.27	32.61	53.56	4.55	.53	4.94	63.83	1.60	24.39	6,047	10,919	12,682
Almond......	11	6.59	9.34	33.15	51.22	6.27	.64	4.70	62.15	1.29	25.28	5,743	10,337	12,255
Rock Springs.	12	6.89	9.90	35.59	49.93	4.56	.73	4.91	62.53	1.23	25.57	5,758	10,366	12,124

ZONE OF UNALTERED COAL.

Black Rock...	6	7.80	8.47	37.14	46.22	8.16	1.72	5.22	62.40	1.29	21.20	6,116	11,009	13,200
Black Buttes..	5	11.02	9.30	32.87	53.23	4.59	.48	5.08	66.14	1.51	22.23	6,290	11,324	13,160
Almond......	3	12.66	5.97	33.33	56.80	3.88	.61	5.07	68.33	1.40	20.68	6,520	11,736	13,020
Rock Springs.	25	5.86	7.29	36.24	52.46	4.01	1.08	5.45	69.09	1.32	19.17	6,825	12,290	13,837

ZONE OF UNALTERED COAL.

The coal samples collected in 1907 clearly indicated that the phenomena of weathering are not confined to outcrops or shallow prospects, but extend back considerable distances, even several hundred feet, or to water level, in large mines as well as in shallow mines, country banks, and drifts. A large number of these samples show to what extent underground weathering or oxygenation has been effective along mine openings, but practically no samples were collected to show how far below the surface in the belt of weathering the coal was altered. For this reason coal samples were collected in the summer of 1908 from three of the four coal groups in the Rock Springs field to ascertain if possible to what depth the weathered belt extends below the surface where the coal has not previously been open and exposed to the air. In making these tests it was considered best to collect samples from some of the new mines recently opened, as they offered the best opportunities to sample fresh surfaces of coal from the outcrop down to the lowest depths of the workings. New mines were opened in 1907 and 1908 on the Rock Springs coal group by the Gunn-Quealy Coal Company at Gunn, on the Almond coal group by the Rock Springs and Wyoming Coal Company east of Point of Rocks, and on the Black Buttes coal group by the Rock Springs-Gibraltar Coal Company southwest of Black Buttes. At each of these localities a number of samples were taken, and the results of the analyses are given below. It was not considered necessary to take samples at the surface in the vicinity of the mines, as a sufficient number of analyses of samples collected the previous year showed the conditions in shallow or surface prospects at or near the surface.

COALS OF THE ROCK SPRINGS GROUP.

In the following table are the results of analyses of samples of the Rock Springs coal obtained at Gunn:

Analyses[a] *of coal from the Rock Springs coal group, showing the effect of weathering at various depths below the surface.*

[Samples taken in the Gunn-Quealy mines, Gunn, Wyo.; sec. 8, T. 19 N., R. 104 W. F. M. Stanton, chemist in charge.]

No.	Sample taken.			Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.	
	Mine.	Distance down manway (feet).	Thickness of cover (feet).		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7090	B	10	24	17.30	23.30	31.94	41.49	3.27	0.53	5.53	50.17	1.04	39.46	4,500	8,100
					7.25	38.62	50.18	3.95	.64	4.36	60.66	1.26	29.13	5,441	9,794
						41.64	54.10	4.26	.69	3.83	65.41	1.36	24.45	5,867	10,561
						43.49	56.51	......	.72	4.00	68.32	1.42	25.54	6,128	11,030
7089	B	80	56	9.10	13.43	34.92	49.41	2.24	.95	5.76	64.33	1.21	25.51	6,365	11,455
					4.76	38.42	54.36	2.46	1.05	5.23	70.77	1.33	19.16	7,002	12,604
						40.33	57.08	2.59	1.10	4.93	74.31	1.40	15.67	7,352	13,234
						41.40	58.60	......	1.13	5.06	76.29	1.44	16.08	7,548	13,586
7092	B	150	70	11.50	15.91	33.23	47.13	3.73	1.10	5.99	61.76	1.29	26.13	6,044	11,879
					4.98	37.55	53.25	4.22	1.24	5.33	69.78	1.46	17.97	6,829	12,292
						39.52	56.04	4.44	1.31	5.02	73.44	1.53	14.26	7,187	12,937
						41.36	58.64	......	1.37	5.25	76.85	1.60	14.93	7,521	13,538
5805	A	200	96	5.30	13.59	34.99	48.12	3.30	1.02	5.89	64.12	1.27	24.40	6,396	11,513
					8.75	36.95	50.81	3.49	1.08	5.60	67.71	1.34	20.78	6,754	12,157
						40.49	55.70	3.81	1.18	5.07	74.20	1.47	14.27	7,402	13,324
						42.09	57.91	......	1.23	5.27	77.14	1.53	14.83	7,695	13,852
5806	B	300	225	4.90	13.65	34.83	50.08	1.44	.98	6.05	64.53	1.18	25.82	6,590	11,862
					9.21	36.62	52.66	1.51	1.03	5.79	67.85	1.24	22.58	6,929	12,473
						40.34	57.99	1.67	1.13	5.25	74.73	1.37	15.85	7,632	13,738
						41.02	58.98	......	1.15	5.34	75.99	1.40	16.12	7,762	13,971
7091	B	800	360	12.40	15.71	33.50	48.40	2.39	.93	6.11	63.11	1.30	26.16	6,191	11,144
					3.78	38.24	55.25	2.73	1.06	5.40	72.04	1.48	17.29	7,067	12,721
						39.74	57.42	2.84	1.10	5.17	74.87	1.54	14.48	7,345	13,221
						40.90	59.10	......	1.13	5.32	77.06	1.58	14.91	7,559	13,606
8534	B	1,100	374	9.40	17.61	31.09	47.50	3.80	1.13	6.24	60.36	1.30	27.17	5,982	10,768
					9.06	34.32	52.43	4.19	1.25	5.74	66.62	1.44	20.76	6,603	11,885
						37.73	57.66	4.61	1.37	5.19	73.26	1.58	13.99	7,260	13,068
						39.55	60.45	......	1.44	5.44	76.80	1.66	14.66	7,611	13,700

[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).

The results of analyses of Rock Springs coal taken from surface prospects in the belt of weathering are given in Bulletin 341, page 271, Nos. 5812, 5372, 5371, 5376, 5814, 5809, 5813, and 7090. Analyses of coals in this group showing the various stages of underground weathering as a result of exposure to air appear in Bulletin 341, pages 270 and 271, Nos. 5694, 5696, 5698, 5697, 6043, 5370, 5369, 5368, 5357, 5373, 5699; and in the present report, page 243, No. 6791.

Analyses of good unaltered coal obtained near the surface in small country mines are Nos. 6796 and 6799 of this report (p. 242). No. 6796 was collected from the Millor mine, in the NW. ¼ NW. ¼ sec. 24,

T. 17 N., R. 105 W., and No. 6799 from the Kent mine, in the NE. ¼ NE. ¼ sec. 14, T. 17 N., R. 105 W. In both of these mines the coal has been exposed for some time, but every winter fresh coal is taken out for ranch use, so that it was possible to get unaltered coal from the working face back only 40 and 75 feet, respectively, from the mouth of the mine.

A comparative study of the analyses of the Rock Springs coal sampled at various places and depths in the Rock Springs, Sweetwater, Blairtown, Gunn, and Superior mines shows that there is a very small range in the percentages of the constituents. This indicates that the unaltered coal is remarkably uniform and bears a regional resemblance in the various mines.

Range in percentages of constituents and heat values of Rock Springs coal, as shown by analyses of air-dried samples from the mines at Rock Springs, Sweetwater, Blairtown, Gunn, and Superior.[a]

Moisture	5.51- 10.85
Volatile matter	33.35- 39.66
Fixed carbon	49.16- 55.25
Ash	1.51- 9.30
Sulphur	.77- 1.38
Hydrogen	5.22- 5.79
Carbon	64.17- 73.51
Nitrogen	1.15- 1.57
Oxygen	16.55- 22.91
Calories	6,352- 7,310
British thermal units	11,435-13,158

The twenty-five unweathered samples collected give no indication that the coal improves in depth or that the weathered zone extends very far below the surface of the ground, or, as often supposed, to the top of the ground-water level. Samples were collected near the top of the unaltered coal, approximately 50 feet below the surface, and at various other places throughout the mines to a depth of about 2,000 feet below the surface, that of No. 5358, sampled in entry No. 51 of the Union Pacific mine No. 1 at Rock Springs. Of all the mine samples collected the one showing the highest calorific value in the air-dried state is No. 6772, from the Wyoming Coal and Coke mine at Blairtown, taken 96 feet below the surface near the end of the second entry south, about 400 feet southwest of the slope opening on bed No. 3. This sample gives 13,158 British thermal units when air dried and heads the list of samples for dry coal with 13,811 British thermal units. On a pure-coal basis only six of the 25 samples show calorific values greater than 14,000 British thermal units. Of these six, four have higher values than sample No. 6772 and all come from shallow or very moderate depths in the mines. The order of these six samples is as follows:

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[a] For complete analyses see Bull. U. S. Geol. Survey No. 341, 1909, p. 270; all analyses on the page cited, except Nos. 5694 and 5696, represent mine samples.

Calorific values of pure coal, samples from Rock Springs coal group.

	British thermal units.
5926	14,272
5928	14,162
5366	14,119
5785	14,114
6772	14,069
5365	14,053

From the table on page 289 it will be seen that the weathered coal zone does not reach a depth of 56 feet below the surface but extends to a depth greater than 24 feet, the division line at the Gunn-Quealy mine lying somewhere between these two limits. It is evident also that the coal below the belt of weathering does not improve in quality with increasing depth. On a pure-coal basis the unaltered Rock Springs coal has a calorific efficiency, in round numbers, of 13,600 to 14,300 British thermal units.

COALS OF THE ALMOND GROUP.

The results on the Almond coals are presented below.

Analyses[a] of coal from the Almond coal group, showing the effect of weathering at various depths below the surface.

[Samples taken in the Rock Springs and Wyoming mine, Point of Rocks, Wyo., sec. 26, T. 20 N., R. 101 W. F. M. Stanton, chemist in charge.]

	Sample taken.				Proximate analysis.				Ultimate analysis.					Heat value.	
No.	Bed.	Distance along entry (feet).	Thickness of cover (feet).	Air-drying loss.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7088	Upper	50	37	7.50	14.26 7.31	33.24 35.93 38.77 41.38	47.06 50.88 54.89 58.62	5.44 5.88 6.34	0.74 .81 .87 .93	4.69 4.17 3.63 3.88	54.16 58.55 63.17 67.45	1.35 1.46 1.57 1.68	33.62 29.13 24.42 26.06	4,630 5,005 5,400 5,766	8,334 9,009 9,720 10,379
7095	...do.	150	81	8.60	13.96 5.87	31.14 34.07 36.19 37.99	50.81 55.58 59.06 62.01	4.09 4.48 4.75	.56 .61 .65 .68	5.38 4.84 4.45 4.67	60.29 65.96 70.07 73.56	1.26 1.38 1.46 1.53	28.42 22.73 18.62 19.56	5,653 6,185 6,570 6,897	10,175 11,133 11,826 12,415
[b] 5351	...do.	227	103	2.40	16.01 13.95	33.17 33.98 39.49 41.67	46.43 47.57 55.28 58.33	4.39 4.50 5.23	.76 .78 .90 .95	5.04 4.89 3.88 4.09	59.36 60.82 70.68 74.58	1.19 1.22 1.42 1.50	29.26 27.79 17.89 18.88	5,474 5,609 6,517 6,878	9,853 10,095 11,731 12,379
5352	Lower	575	200	2.80	16.61 14.21	30.24 31.11 36.26 40.75	43.96 45.22 52.72 59.25	9.19 9.46 11.02	.68 .70 .82 .92	5.28 5.11 4.11 4.62	55.64 57.24 66.72 74.98	1.10 1.13 1.32 1.49	28.11 26.36 16.01 17.99	5,230 5,381 6,272 7,049	9,414 9,685 11,290 12,688
7087	Upper	300	136	12.00	16.92 5.58	28.36 32.23 34.14 35.59	51.32 58.33 61.77 64.41	3.40 3.86 4.09	.55 .62 .66 .69	5.75 5.02 4.66 4.86	60.61 68.88 72.96 76.07	1.24 1.41 1.49 1.55	28.45 20.21 16.14 16.83	5,785 6,575 6,963 7,260	10,413 11,835 12,533 13,068
7094	...do.	500	128	12.40	17.92 6.30	29.51 33.69 35.96 37.44	49.30 56.28 60.06 62.56	3.27 3.73 3.98	.50 .57 .61 .64	5.87 5.13 4.73 4.93	59.46 67.87 72.44 75.44	1.24 1.41 1.51 1.57	29.66 21.29 16.73 17.42	5,678 6,482 6,918 7,204	10,220 11,668 12,452 12,967
7102	...do.	1,000	132	13.60	18.83 6.05	29.45 34.08 36.28 37.93	48.20 55.80 59.38 62.07	3.52 4.07 4.34	.55 .64 .68 .71	5.90 5.08 4.69 4.90	58.97 68.25 72.65 75.95	1.21 1.40 1.49 1.56	29.85 20.56 16.15 16.88	5,619 6,504 6,923 7,237	10,114 11,707 12,461 13,027

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[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).

[b] Analysis No. 5351 as published in Bulletin 341, p. 271, is incorrect.

The results of the analyses of the Almond coal taken from surface prospects in the belt of weathering are given in Bulletin 341, page 272, Nos. 5950, 5597, 5599, 5348, 5349, and 5350.

Exceptionally good illustrations of underground weathering or oxygenation are given in the Rock Springs and Wyoming mine at Point of Rocks and in the old No. 6 mine at Rock Springs. The mine east of Point of Rocks was opened in 1868 and operated to December, 1869, about 7,256 tons of coal being taken out. From that date to 1907 the mine was not worked. Samples Nos. 5351 and 5352 (Bulletin 341, pp. 271, 272) were collected from the mine in 1907, while the old mine was being cleaned out. On a comparison of the analyses of these two samples with those of the last three in the above table the altered condition of the coal represented by the former will be apparent. Sample No. 5351 was taken from the upper bed at the end of a fresh unfinished crosscut about 20 feet from the old drift opened in 1868–69, 103 feet below the surface and 227 feet from the mouth of the mine. Sample No. 5352 was taken from the lower bed about 70 feet below the upper bed, at the end of an old drift 575 feet from the mouth of the mine.

Old No. 6 mine at Rock Springs, opened on a coal bed of the Almond group in 1882, continued in operation until 1886 and was then abandoned. Analyses No. 6042 (Bulletin 341, p. 271) and No. 6773 (p. 243 of the present report) show the same amount of oxygenation due to exposure to the air. Both of these samples were collected from the main slope approximately 300 feet from the mouth of the mine. Similar results are indicated in samples Nos. 5804, 5353, and 5347 (Bulletin 341, pp. 271, 272) and in Nos. 6797, 7095, 6775, and 7088 (p. 243 of this volume). The above table shows that back from the old mine openings the weathered coal zone does not extend to a depth of more than 100 feet below the surface. How much less the depth is can not be told from the samples here collected, as they were taken along the old entries. The table also shows that on a pure-coal basis the heat value of the unaltered Almond coal approximates 13,000 British thermal units.

COALS OF THE BLACK BUTTES GROUP.

In the subjoined table are the results for the Black Buttes coal.

Analyses[a] of coal from the Black Buttes coal group, showing the effect of weathering at various depths below the surface.

[Samples taken in the Rock Springs-Gibraltar coal mine, Black Buttes, Wyo., sec. 20, T. 18 N., R. 100 W. F. M. Stanton, chemist in charge.]

No.	Sample taken.			Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.	
	Bed.	Distance down slope (feet).	Thickness of cover (feet).		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
7103	Upper	50	10	13.10	17.22	30.32	48.23	4.23	0.35	5.36	56.22	1.51	32.33	5,216	9,389
					4.74	34.89	55.50	4.87	.40	4.49	64.69	1.74	23.81	6,002	10,804
						36.63	58.26	5.11	.42	4.17	67.91	1.82	20.57	6,301	11,342
						38.60	61.40	......	.44	4.39	71.57	1.92	21.68	6,641	11,954
7170	...do.	100	40	7.90	18.87	28.93	48.07	4.13	.43	5.82	59.20	1.43	28.99	5,607	10,093
					11.91	31.41	52.20	4.48	.47	5.36	64.28	1.55	23.86	6,088	10,958
						35.66	59.25	5.09	.53	4.59	72.97	1.76	15.06	6,911	12.440
						37.57	62.43	......	.56	4.84	76.88	1.85	15.87	7,281	13,106
5808	...do.	130	50	5.80	18.86	29.17	47.85	4.12	.49	5.64	58.96	1.45	29.34	5,713	10,283
					13.86	30.97	50.80	4.37	.52	5.31	62.59	1.54	25.67	6,065	10,916
						35.95	58.98	5.07	.60	4.38	72.65	1.79	15.51	7,040	12,672
						37.87	62.13	......	.63	4.61	76.53	1.89	16.34	7,416	13,349
5811	Lower	140	(a)	6.10	19.42	31.02	45.02	4.54	.51	......	......	......	......	5,677	10,219
					14.18	33.04	47.94	4.84	.54	......	......	......	......	6,046	10,882
						38.50	55.87	5.63	.63	......	......	......	......	7,045	12,680
						40.80	59.20	......	.67	......	......	......	......	7,465	13,436
7097	Upper	150	60	13.10	18.69	29.23	48.35	3.73	.44	5.79	58.45	1.41	30.18	5,582	10,047
					6.43	33.64	55.64	4.29	.51	4.98	67.26	1.62	21.34	6,423	11,561
						35.95	59.46	4.59	.54	4.56	71.89	1.73	16.69	6,865	12,357
						37.68	62.32	......	.57	4.78	75.34	1.81	17.50	7,195	12,951
7096	...do.	225	75	14.50	19.54	28.21	47.85	4.40	.37	5 89	57.34	1.40	30.60	5,465	9,837
					5.90	32.99	55.96	5.15	.43	5.01	67.07	1.64	20.70	6,392	11,506
						35.06	59.47	5.47	.46	4.62	71.27	1.74	16.44	6,792	12,226
						37.09	62.91	......	.49	4.89	75.40	1.84	17.38	7,185	12,933
7093	...do.	355	75	15.60	20.77	28.38	47.12	3.73	.36	5.98	57.11	1.06	31.76	5,507	9,913
					6.12	33.62	55.84	4.42	.43	5.03	67.66	1.26	21.20	6,526	11,747
						35.81	59.48	4.71	.45	4.63	72.08	1.34	16.79	6,950	12,510
						37.58	62.42	......	.47	4.86	75.64	1.41	17.62	7,293	13,127

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[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).

[b] 78 feet below upper bed.

No samples of coal for analysis were collected from surface prospects on the Black Buttes beds. The conditions here are much the same as those for the Almond coals. From the above table it may be seen that the zone of surface weathering at this mine extends approximately 100 feet down the slope and is about the same in the lower and the upper bed, although the lower bed lies 78 feet stratigraphically below the upper bed.

Slight weathering was observed in samples Nos. 5951 and 5810, collected from the ends of prospects open 90 and 190 feet, respectively; also in sample No. 5952, from the old abandoned Black Buttes mine southeast of Black Buttes station, collected 250 feet down the entry from the mouth of the mine and 10 feet above water level. Complete analyses of these three samples are given in the following table:

Analyses[a] of coal from the Black Buttes coal group, showing the effect of weathering along mine entries and prospect pits.

[F. M. Stanton, chemist in charge.]

No.	Sample taken.		Air-drying loss.	Proximate analysis.				Ultimate analysis.					Heat value.	
	Mine.	Distance along entry (feet).		Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
5810	Prospect.	190	3.70	15.14	32.58	47.88	4.40	0.62	......	......	......	......	5,766	10,379
				11.88	33.83	49.72	4.57	.64	......	......	......	......	5,988	10,778
					38.39	56.42	5.19	.73	......	......	......	......	6,795	12,235
					40.49	59.51	......	.77	......	......	......	......	7,167	12,905
5952	Mine.	250	3.60	12.85	30.36	52.48	4.31	.56	5.21	60.27	1.47	28.18	5,877	10,579
				9.60	31.49	54.44	4.47	.58	4.99	62.52	1.53	25.91	6,096	10,974
					34.83	60.23	4.94	.64	4.34	69.16	1.69	19.23	6,743	12,137
					36.64	63.36	......	.67	4.56	72.76	1.78	20.23	7,093	12,768
5951	Prospect.	90	6.20	13.92	29.50	52.49	4.09	.52	......	......	......	......	5,776	10,397
				8.23	31.45	55.96	4.36	.55	......	......	......	......	6,158	11,084
					34.27	60.98	4.75	.60	......	......	......	......	6,710	12,078
					35.98	64.02	......	.63	......	......	......	......	7,045	12,680

[a] Four analyses are given for each sample, arranged as follows: As received, air-dried, dry coal, pure coal (moisture and ash free).

From the analyses given above it appears that the weathered zone of the Black Buttes coal extends approximately 100 feet down the dip of the beds and 40 feet below the surface. The calorific values of unaltered air-dried coal are between 11,500 and 12,000 British thermal units; on a basis of pure coal the values approach 13,000 British thermal units.

COALS OF THE BLACK ROCK GROUP.

No large mines have been opened on the Black Rock beds, but there are several small country mines from which a small amount of coal is taken annually for local ranch use, so that it is possible to get good samples of unaltered coal. The results of analyses of Black Rock coal taken from surface prospects in the belt of weathering are given in Bulletin 341, page 272, Nos. 5375 and 5367. Both of these samples give in the calorimeter approximately one-half the efficiency of the unaltered coal sampled in the small country mines.

Two illustrations of partial weathering and oxygenation are afforded by samples No. 5374 (Bulletin 341, p. 272) and No. 6771 (p. 245 of the present report). All other samples of Black Rock coal were taken from freshly cut faces of small mines that had passed through the weathered zone and furnished good samples of unaltered coal As all these samples were taken at distances from 30 to 150 feet from the mouth of the mine it shows that the belt of weathering does not extend very far below the surface. The heat values as shown by samples Nos. 6794, 6774, and 6795, page 245 of this report, and Nos. 5930, 5803, and 5802, page 272 of Bulletin 341, may not be so high as those of the coal taken from greater depths. From the regularity here shown it appears that most if not all of these samples were obtained near or below the lower limit of the weathered zone. The calorific value of unaltered air-dried coal lies between 11,000 and 11,650 British thermal units; on the basis of pure coal it exceeds 13,000 British thermal units.

CONCLUSIONS.

It was not considered advisable in this preliminary paper to take up the results of weathering observed by other men in different localities under somewhat different conditions, or to refer to published articles on the weathering of coal. This was left for a fuller discussion of the subject of weathering to be taken up at some future time. In presenting the foregoing observations on the weathering of coal the factors involved are restricted entirely to those present in the Rock Springs field, and the following conclusions are therefore based on these local data.

The results obtained in the Rock Springs field indicate that so far as coal decomposition or deterioration is concerned the belt of weathering in arid regions may be divided into two members. Coal in the lower member of the belt apparently shows no greater effect of weathering or deterioration than the coal below the level of ground water, but coal in the upper member, or in the surficial belt of weathering, shows remarkable deterioration and decomposition. The protection of the coal above the level of ground water in the lower member of the belt of weathering may in part be accounted for by the accompanying beds of clay and shale, which tend to shut out the oxygen and free circulation almost as completely as the ground water.

On comparison of averages in the table of analyses of Rock Springs coal showing the three stages of alteration it will be seen that the moisture and oxygen are greatly in excess in the surficial belt of weathering and that the fixed carbon and carbon both show a corresponding deficiency, or a loss of approximately 20 per cent from the carbon content in the unaltered mine samples. Volatile matter, ash, sulphur, hydrogen, and nitrogen are fairly uniform in the three stages. There is, however, a slight increase in the ash content in the weathered belt and a decrease in the sulphur content, which indicates that some of the iron sulphide in the coal has been changed to iron oxide. This view is further supported by the iron stain or oxide seen on the face of the coal in the air-slaked or weathered stage. The sulphur, probably combined with hydrogen, is taken into solution in the underground water and carried off as hydrogen sulphide.

The values for calories and British thermal units show that the factors of weathering are negligible in the Rock Springs coal in the Gunn B mine at a point 80 feet down the slope, or 12 feet vertically below the opening of the mine, where the coal has a cover of 56 feet. On an ash and moisture free basis the unweathered coal shows over 13,700 British thermal units, the average for the 25 unweathered Rock Springs coal samples being 13,875 British thermal units. In the Almond coal weathering seems to have altered the coal to a distance of more than 227 feet along the entry and 103 feet below the surface. Part of this weathering no doubt is due to the circulation of air along the old mine entry; and in the lower bed the alteration extends back more than 575 feet. Unweathered coal from this mine gives over 13,000 British thermal units on the moisture and ash free basis. In the Black Buttes coal weathering seems to have progressed to a point 100 feet down the slope, or approximately 40 feet below the surface. Unweathered coal from this mine has a fuel value of more than 13,100 British thermal units on the moisture and ash free basis.

The analyses show that the proportions of the various constituents are about the same whether the sample of coal was taken near the surface or at a greater depth, the only exception being the oxygen, which in every case is perceptibly higher near the surface than at greater depths and by its excess shows the extent of the surficial belt of weathering. The ash, sulphur, and hydrogen content remain fairly constant. There appears to be a slight increase in the amount of hydrogen and ash in the samples obtained near the surface, with a corresponding decrease in the amount of sulphur. It appears from this that the belt of surficial weathering is one of marked oxidation and in this field for the most part lies near the surface, in few places, if anywhere, extending to the ground-water level. If the coal is not open or exposed to the air, the weathered zone does not as a rule extend more than 150 feet down the dip of the beds, or 50 feet below the surface. Along slopes and mine or prospect entries the coal weathers back several hundred feet from the mouth of the mine and several hundred feet below the surface. It is known that in one old mine the coal has changed at least 20 feet back from the face of an old entry approximately 227 feet down in the mine and that deterioration extends back into the mine 575 feet from its mouth. It is very probable that in an abandoned mine remaining open to the air oxygenation in time extends throughout the mine and that the coals of lower grade show the effect of oxygenation much more than the high-grade coals.

COAL OF THE DENVER BASIN, COLORADO.

By George C. Martin.

During the summer of 1908 the writer made a hasty reconnaissance examination of the coal field lying just east of the Front Range of the Rocky Mountains and extending from a point somewhat south of the city of Denver to the north line of the State. As the primary object of the work was the classification of the land, only sufficient time was devoted to the stratigraphy and structure of the rocks to enable the writer to compare his conclusions with those of the previous report[a] by the Geological Survey on this field. No important difference was found, and since the stratigraphic conditions to the north as far as the Wyoming state line are essentially the same as in the Denver region the statements of that report may be considered as applying to the whole field covered by the present paper.

In general the sedimentary formations are steeply upturned against the mountains, but a few miles away the effect of the uplift disappears and the strata are either horizontal or dip slightly toward the east at about the same rate as the slope of the plain. The structure is somewhat complicated near the mountain front by the sharp upturning of the rocks and by minor folds and small faults, which have caused considerable trouble in the mining of coal in this district. This condition, however, is local, and as the throw of the faults is small it has not proved to be a great detriment to the field.

The principal coal beds occur in the lower part of the Laramie formation, which outcrops in a narrow band from a point west of Sedalia nearly to Marshall and there on account of faults and flatter dips expands into a wide belt of outcrop which extends northeastward from Marshall to Louisville and Erie, thence northward almost to the Wyoming state line, where it is covered and concealed by a wide overlap of Tertiary rocks.

Active mining on these coal beds has been carried on for a long time, and in 1908 the combined coal production of Weld, Larimer, Jefferson, Adams, and Arapahoe counties, in which they are situated, was 509,038 short tons. The coal meets with a ready sale, although it is inferior to much of the coal from other fields of Colorado, its nearness to a large city and to a region of intensive farming more than offsetting its poor quality.

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[a] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: Mon. U. S. Geol. Survey, vol. 27, 1896.

The coal generally is shiny and black and is inclined to be massive except as it separates along the planes of bedding. Joints are poorly developed and the coal breaks along irregular lines rather than in prisms like coal of a higher grade. On exposure to the air it rapidly parts with its moisture and in the consequent shrinking it breaks to pieces or air slacks. Its percentage of moisture is large, and consequently shipment is expensive. Generally it is shipped in box cars to prevent the escape of moisture and the breaking down of the lump coal.

During the present work a number of samples were taken from the mines of this basin for chemical analysis, and as the sampling and chemical work were done uniformly the results are particularly valuable in that they may be compared directly without the possibility of doing injustice to the product of any particular mine. The sampling, which is by far the most important part of the analytical work, was done by cutting a channel across the coal bed, including everything except the partings or lenses of foreign material which are present at many places. This cut included the entire bed or such part or parts thereof as are mined at that particular place. After being crushed in the mine to avoid loss of moisture and quartered in the usual way the final sample, weighing about 3 pounds, was sent to the chemical laboratory in sealed galvanized-iron cans. By this method the sample reached the laboratory in practically the same condition as it was in at the mine. As in this condition it may have included considerable moisture that in no way belonged to the coal, the sample was air dried in the laboratory to drive off all excess or easily separated moisture and then analyzed in the regular manner.

Each analysis is given in four forms, so that it may be convenient for a variety of uses. The different forms are as follows:

1. As received: Analysis showing composition of the coal as it comes from the mine.

2. Air dried: Analysis of sample after it has been exposed to a temperature a little above that of the ordinary atmosphere and to a current of air. The sample in this condition probably is nearly the same as commercial coal, especially if the latter is shipped in box cars.

3. Dry coal: Analysis recalculated to represent the coal after all moisture has been removed. This form is valuable for purposes of comparison, but it should be clearly understood that it does not represent the coal as mined or as it reaches the consumer.

4. Pure coal: This heading is not strictly correct, for it implies that no foreign material is present, whereas the sulphur has not been eliminated. It is a convenient term, however, and is used in this report to represent coal in the hypothetical condition of having all its moisture and ash removed. Like form No. 3, this is convenient for certain calculations, but in no way represents the coal actually mined and used.

The chemical analyses of samples collected during the course of this work are as follows:

Analyses of coal samples from the Denver Basin, Colorado.

[A. C. Fieldner, chemist in charge.]

Laboratory No.	Location.			Thickness.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T.	R. W.	Coal bed.		Part sampled.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft.	*in.*	*Ft.*	*in.*													
6371	24	4 N.	65	2	8½	2	8½	21.9	As received	29.1	28.5	36.6	5.82	0.30	6.55	48.95	1.03	37.35	4,667	8,401
									Air dried	9.3	36.5	46.8	7.45	.38	5.27	62.67	1.32	22.91	5,976	10,757
									Dry coal	....	40.2	51.6	8.21	.42	4.67	69.07	1.45	16.18	6,585	11,853
									Pure coal[a]	....	43.8	56.2	....	.46	5.09	75.24	1.58	17.63	7,174	12,913
6372	33	3 S.	70	2		2		9.5	As received	18.5	35.5	40.3	5.67	.57	5.76	53.15	.95	33.90	5,217	9,391
									Air dried	10.0	39.2	44.5	6.26	.63	5.19	58.73	1.05	28.14	5,765	10,377
									Dry coal	....	43.5	49.5	6.96	.70	4.54	65.27	1.17	21.36	6,406	11,531
									Pure coal	....	46.8	53.2	....	.76	4.88	70.15	1.26	22.95	6,885	12,393
6373	24	4 N.	65	2	8	2	8	22.9	As received	29.7	27.7	36.5	6.10	.35	6.47	47.16	1.06	38.86	4,486	8,075
									Air dried	8.8	35.9	47.4	7.91	.45	5.10	61.17	1.37	24.00	5,818	10,472
									Dry coal	....	39.3	52.0	8.68	.50	4.51	67.07	1.51	17.73	6,379	11,482
									Pure coal	....	43.1	56.9	....	.55	4.94	73.45	1.65	19.41	6,986	12,575
6374	33	2 N.	68	8		6	3	12.7	As received	21.0	31.2	44.2	3.61	.38	6.13	56.45	1.13	32.30	5,556	10,001
									Air dried	9.6	35.7	50.6	4.14	.44	5.41	64.65	1.30	24.06	6,364	11,455
									Dry coal	....	39.5	55.9	4.57	.48	4.80	71.50	1.43	17.22	7,037	12,667
									Pure coal	....	41.4	58.6	....	.50	5.03	74.92	1.50	18.05	7,374	13,273
6375	30	2 N.	67	8	4	4	6	20.7	As received	25.6	28.0	41.1	5.34	.36	6.27	51.81	1.11	35.11	5,101	9,182
									Air dried	6.2	35.3	51.8	6.74	.46	5.00	65.33	1.40	21.07	6,432	11,578
									Dry coal	....	37.6	55.2	7.18	.48	4.60	69.65	1.49	16.60	6,857	12,343
									Pure coal	....	40.5	59.5	....	.52	4.96	75.04	1.61	17.87	7,388	13,298
6406	32	7 N.	65	2	10½	2	10½	26.1	As received	31.4	28.1	35.1	5.35	.46	6.68	45.57	.96	40.98	4,418	7,952
									Air dried	7.2	38.1	47.5	7.24	.62	5.12	61.66	1.30	24.06	5,979	10,762
									Dry coal	....	41.0	51.2	7.80	.67	4.65	66.44	1.40	19.04	6,441	11,594
									Pure coal	....	44.5	55.5	....	.73	5.04	72.06	1.52	20.65	6,986	12,575
6407	29	3 N.	66	5		1	1	24.5	As received	28.1	29.8	37.9	4.22	.37	6.65	50.46	1.00	37.30	4,863	8,753
									Air dried	4.8	39.5	50.1	5.59	.49	5.20	66.83	1.32	20.57	6,441	11,594
									Dry coal	....	41.5	52.6	5.87	.51	4.91	70.20	1.39	17.12	6,765	12,177
									Pure coal	....	44.1	55.9	....	.54	5.22	74.58	1.48	18.18	7,187	12,937

6408	29	3 N	66	5		2	4	24.1	As received	28.9	28.8	37.3	5.02	.46	6.64	48.36	.93	38.59	4,703	8,465
									Air dried	6.3	38.0	49.1	6.62	.61	5.22	63.72	1.22	22.61	6,196	11,153
									Dry coal	....	40.5	52.4	7.06	.65	4.82	68.02	1.31	18.14	6.615	11,907
									Pure coal	....	43.6	56.4	....	.70	5.19	73.19	1.41	19.51	7,118	12,812
6433	24	10 N	68	5	1	5	1	24.9	As received	29.3	29.0	32.7	9.00	3.43	6.28	42.88	.75	37.66	4,149	7,468
									Air dried	5.9	38.5	43.6	11.99	4.57	4.67	57.10	1.00	20.67	5,525	9,945
									Dry coal	....	41.0	46.3	12.74	4.85	4.27	60.68	1.06	16.40	5,871	10,568
									Pure coal	....	46.9	53.1	....	5.56	4.89	69.54	1.21	18.80	6,728	12,110
6593	23	4 S.	70	15	8	14	8	14.8	As received	23.5	34.1	35.0	7.42	.80	6.02	49.26	.60	35.90	4,681	8,426
									Air dried	10.3	40.0	41.0	8.71	.94	5.14	57.82	.70	26.69	5,494	9,889
									Dry coal	....	44.6	45.7	9.70	1.05	4.46	64.41	.78	19.60	6,120	11,016
									Pure coal	....	49.4	50.6	....	1.16	4.94	71.33	.86	21.71	6,778	12,200
6594	23	4 S.	70	15	8	3	8	15.4	As received	23.2	34.1	36.9	5.8	.64	....	....	....	....	....	....
									Air dried	9.2	40.3	43.7	6.8	.76	....	....	....	....	....	....
									Dry coal	....	44.4	48.1	7.5	.83	....	....	....	....	....	....
									Pure coal	....	48.0	52.0	....	.90	....	....	....	....	....	....
6832	6	1 S.	68	13	2	4		11.4	As received	18.8	31.1	46.2	3.86	.27	6.18	57.47	.99	31.23	5,506	9,911
									Air dried	8.4	35.1	52.1	4.36	.31	5.54	64.87	1.12	23.80	6,215	11,187
									Dry coal	....	38.3	56.9	4.76	.33	5.04	70.82	1.22	17.83	6,785	12,213
									Pure coal	....	40.3	59.7	....	.35	5.29	74.36	1.28	18.72	7,124	12,823
6833		1 S.	68	13	2	5	4	13.0	As received	19.7	30.7	43.6	6.00	.33	6.02	56.54	1.02	30.09	4,799	8,638
									Air dried	7.6	35.4	50.1	6.90	.38	5.27	64.99	1.17	21.29	5,516	9,929
									Dry coal	....	38.3	54.2	7.47	.41	4.78	70.37	1.27	15.70	5,973	10,751
									Pure coal	....	41.4	58.6	....	.44	5.17	76.05	1.37	16.97	6,455	11,619
6834	6	1 S.	68	13	2	3	8	16.5	As received	21.2	28.1	44.2	6.53	.46	5.93	55.37	.99	30.72	5,145	9,262
									Air dried	5.6	33.7	52.9	7.82	.55	4.91	66.31	1.18	19.23	6,162	11,092
									Dry coal	....	35.6	56.1	8.28	.58	4.54	70.21	1.26	15.13	6,525	11,745
									Pure coal	....	38.9	61.1	....	.63	4.95	76.54	1.38	16.50	7,114	12,805
6835		1 S.	70	6	3	6		12.6	As received	18.9	30.8	47.0	3.29	.26	5.90	58.59	1.09	30.87	5,407	9.733
									Air dried	7.1	35.3	53.8	3.77	.30	5.15	67.03	1.25	22.50	6,187	11,137
									Dry coal	....	38.0	58.0	4.05	.32	4.68	72.21	1.34	17.40	6,664	11,955
									Pure coal	....	39.6	60.4	....	.33	4.88	75.26	1.40	18.13	6,945	12,501
6836	24	1 S.	70	7		7		9.9	As received	17.3	32.1	46.0	4.64	.31	5.96	58.51	1.14	29.44	5,526	9,947
									Air dried	8.2	35.6	51.1	5.15	.34	5.39	64.94	1.27	22.91	6,133	11,039
									Dry coal	....	38.8	55.6	5.61	.37	4.89	70.77	1.38	16.98	6,684	12,031
									Pure coal	....	41.1	58.9	....	.39	5.18	74.97	1.46	18.00	7,081	12,746
6837	8	1 S.	69	10	1	4	7	14.1	As received	20.5	30.5	44.0	5.03	.34	6.10	56.17	1.12	31.24	5,291	9,524
									Air dried	7.4	35.5	51.2	5.85	.40	5.27	65.39	1.30	21.79	6,159	11,086
									Dry coal	....	38.4	55.3	6.32	.43	4.81	70.61	1.41	16.42	6,651	11,972
									Pure coal	....	41.0	59.0	....	.46	5.13	75.38	1.51	17.52	7,100	12,780

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[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term it is used in this report as noted above.

Analyses of coal samples from the Denver Basin, Colorado—Continued.

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6838	8	1 S.	69	6 8½	6 8	15.1	As received	21.6	27.8	47.0	3.55	.37	5.93	56.06	1.09	33.00	5,282	9,508
							Air dried	7.7	32.8	55.3	4.18	.43	5.00	66.03	1.28	23.08	6,222	11,200
							Dry coal	....	35.5	60.0	4.53	.47	4.51	71.53	1.39	17.57	6,740	12,132
							Pure coal	....	37.2	62.8	....	.49	4.72	74.93	1.46	18.40	7,060	12,708
6839	8	1 S.	69	10 1	3 4	9.8	As received	18.8	30.5	44.5	6.25	.34	6.00	56.35	1.08	29.98	5,360	9,648
							Air dried	10.0	33.8	49.3	6.93	.38	5.44	62.47	1.20	23.58	5,942	10,696
							Dry coal	....	37.6	54.7	7.70	.42	4.81	69.39	1.33	16.35	6,600	11,880
							Pure coal	....	40.7	59.3	....	.46	5.21	75.18	1.44	17.71	7,150	12,870
6840	1	1 S.	69	14 4	6 1	13.4	As received	19.1	30.8	44.3	5.76	.25	5.93	56.38	1.08	30.60	5,342	9,616
							Air dried	6.6	35.6	51.1	6.65	.29	5.13	65.10	1.25	21.58	6,169	11,104
							Dry coal	....	38.1	54.8	7.12	.31	4.70	69.74	1.34	16.79	6,608	11,894
							Pure coal	....	41.0	59.0	....	.33	5.06	75.09	1.44	18.08	7,115	12,807
6841	19	1 N.	68	5 7	5 7	16.7	As received	22.9	29.2	44.4	3.46	.36	6.22	54.94	1.17	33.85	5,305	9,549
							Air dried	7.5	35.0	53.3	4.16	.43	5.23	65.95	1.40	22.83	6,368	11,462
							Dry coal	....	37.9	57.6	4.49	.47	4.76	71.30	1.52	17.46	6,884	12,391
							Pure coal	....	39.7	60.3	....	.49	4.98	74.65	1.59	18.29	7,208	12,974
6842	34	2 N.	68	10 5	8 1	16.2	As received	24.3	27.6	44.8	3.25	.36	6.14	55.28	1.07	33.90	5,209	9,376
							Air dried	9.6	33.0	53.5	3.88	.43	5.18	65.97	1.28	23.26	6,216	11,189
							Dry coal	....	36.5	59.2	4.29	.48	4.54	73.01	1.41	16.27	6,880	12,384
							Pure coal	....	38.1	61.9	....	.50	4.74	76.28	1.47	17.01	7,188	12,938

Location and description of coal samples.

No.	Town.	County.	Name of mine.	Section of coal bed.	Ft.	in.	Location in mine.	Depth below surface.	Condition of sample.
								Feet.	
6371		Weld.	White Ash.	*Coal, bony..... *Coal........... 	 2 2	2 6½ 8½	700 feet northwest of foot of shaft.	85	Dry, fresh.
6372		Jefferson.	Ralston Creek.	*Coal...........	2		500 feet north of opening.	75	Dry, fresh.
6373		Weld.	Farmers.	*Coal..........	2	8	500 feet south of foot of shaft.	70	Dry, fresh.
6374		Weld.	Ideal.	Coal............ *Coal........... 	1 6 8	9 3 	300 feet west of foot of slope.	100	Dry, fresh.
6375		Weld.	Warwick.	Coal............ Shale........... Coal, bony....... Parting. *Coal........... 	2 4 8	8 4 10 6 4	165 feet south of foot of shaft.	115	Dry, fresh.
6406	Eaton.	Weld.	Star.	*Coal...........	2	10½	325 feet southeast of foot of shaft.	50	Dry, fresh.
6407	Platteville.	Weld.	Platteville.	Coal............ Bone and coal.... *Coal........... 	2 1 1 5	4 7 1 	200 feet west of foot of shaft.	56	Dry, fresh.

* Part sampled.

Location and description of coal samples—Continued.

No.	Town.	County.	Name of mine.	Section of coal bed.	Ft.	in.	Location in mine.	Depth below surface. Feet.	Condition of sample.
6408	Platteville.	Weld.	Platteville.	*Coal Bone and coal Coal	2 1 1 5	4 7 1	200 feet west of foot of shaft.	56	Dry, fresh.
6433		Larimer.	Indian Springs.	*Coal Bone	5 1 6	1 1 2	In main entry 700 feet N. 70° E. (magnetic) of mouth of slope.	50	Dry, probably weathered.
6593	Morrison.	Jefferson.	Morrison.	Coal Coal, bony *Coal	 14 15	7 5 8 8	50 feet north of shaft on the 73-foot level.	73	Dry, fresh.
6594	Morrison.	Jefferson.	Morrison.	Coal Coal, bony Coal *Coal	 10 3 15	7 5 11 9 8	Bottom of shaft on 120-foot level.	120	Wet, fresh.
6832	Lafayette.	Adams.	Parkdale.	Coal *Coal Bone and shale Coal	4 4 3 13	10 8 8 2	200 feet east of foot of slope, close to fault.	260	Dry, fresh.
6833	Lafayette.	Adams.	Parkdale.	Coal *Coal Bone and shale Coal	3 5 3 13	6 4 8 8 2	150 feet west of foot of slope.	260	Dry, fresh.

6834	Lafayette.	Adams.	Parkdale.	Coal Bone and shale * Coal	8 3 13	10 8 8 2	150 feet west of foot of slope.	260	Dry, fresh.
6835	Marshall.	Boulder.	Mitchell-Monarch.	* Coal Coal	6 6	 3 3	75 feet north and 350 feet east of foot of shaft.	235	Dry, fresh.
6836	Superior.	Boulder.	Industrial.	* Coal	7		1,200 feet east and 450 feet south of foot of shaft.	250	Dry, fresh.
6837	Louisville.	Boulder.	Acme.	Coal Shale * Coal * Parting. * Coal	5 1 2 10	2 4 8 11 1	800 feet south and 950 feet east of foot of shaft.	185	Dry, fresh.
6838	Louisville.	Boulder.	Acme.	* Coal * Parting * Coal	3 3 6	8 ¼ 8¼	950 feet north and 400 feet east of foot of shaft (north of fault).	200	Dry, fresh.
6839	Louisville.	Boulder.	Acme.	Coal * Coal Shale Coal Parting. Coal	1 3 1 2 10	10 4 4 8 11 1	800 feet south and 950 feet east of foot of shaft.	180	Dry, fresh.
6840	Lafayette.	Boulder.	Rankin.	* Coal Bone and shale Coal Shale Coal	6 4 2 1 14	1 11 4 4	200 feet north and 200 feet east of foot of shaft.	210	Dry, fresh.

*Part sampled.

Location and description of coal samples—Continued.

No.	Town.	County.	Name of mine.	Section of coal bed.			Location in mine.	Depth below surface.	Condition of sample.
					Ft.	in.		Feet.	
6841	Erie.	Weld.	Lehigh.	*Coal	5	7	750 feet north of foot of shaft.	100+	Dry, fresh.
6842		Weld.	Puritan.	Coal *Coal	2 8	4 1	175 feet west of foot of shaft.	110	Dry, fresh.
					10	5			

* Part sampled.

THE SOUTH PARK COAL FIELD, COLORADO.

By Chester W. Washburne.

INTRODUCTION.

The coal field described in this paper is located in the eastern part of South Park, an intermontane depression in central Colorado. The Kenosha Range on the northeast and the Puma Hills on the east of the park are western spurs of the Front Range of the Rocky Mountains. West of the park lies an irregular group of mountains called the Mosquito Range, beyond which is the Leadville mining district.

The following pages contain a brief summary of the results of a reconnaissance made in September, 1908. The topography and geology in the vicinity of the coal outcrops were sketched from traverses carefully tied to land corners, but elsewhere no attempt was made to do detailed work.

No coal is now produced in South Park. Between 1875 and 1893 the King mines, near Como, were worked on a large scale by the Union Pacific Coal Company, but they were abandoned after the best and most easily available coal had been mined. It is probable that extensive operations will not be resumed for many years, because of the difficulty in finding coal beneath the cover of gravel and weathered rock and of the apparent absence of thick coal beds.

GENERAL GEOLOGY.

The general geology of South Park may be briefly summed up in the statement that the park consists of two downthrown fault blocks between the Mosquito Range on the west and the spurs of the Front Range on the east. The eastern fault block, which includes the greater part of the area that is possibly underlain by coal, is a syncline, the eastern limb of which is cut off by the fault throughout the central part of the field. The western fault block, in which the coal formation remains only as a small remnant west of Como, has a monoclinal structure, its beds rising gradually westward to the summit of the Mosquito Range, where they are terminated by the great London and Mosquito faults.[a]

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[a] Geology and mining industry of Leadville, Colo.; Mon. U. S. Geol. Survey, vol. 12, 1886.

The coal beds are involved in both folds and faults. In the western block they dip 45° E. until cut off by the South Park fault underneath Como. In the eastern fault block the coal is folded in a syncline, the eastern part of which has been removed by faulting, as shown on the map (Pl. XVI). A remnant of the east limb of the syncline is preserved at Jefferson Hill, 1 mile north of Jefferson, where the coal bed dips about 50° W. North of this locality the outcrop of the coal bed probably swings around the end of the syncline and runs southward to the prospects in sec. 23, T. 8 S., R. 76 W., where the bed stands nearly vertical. South of these prospects the dips become gradually lower, being about 45° E. at the King mines and 20° E. near the south end of the syncline. On following the coal horizon northward from the south end the dips of the east limb of the syncline are found to vary from 30° to 50° W. until the coal bed again disappears against granite at the Elkhorn fault.

As coal occurs only in the "Laramie" formation, a description of the other formations is not necessary in this paper.

THE COAL.

STRATIGRAPHIC POSITION.

The coal beds of South Park occur in what is presumably the "Laramie" formation, consisting of sandstone with subordinate beds of carbonaceous shale and ranging in thickness from 375 feet down to the vanishing point. No fossils have been found in the formation, but as it rests on a yellow sandstone containing upper Montana marine fossils and is unconformably overlain by conglomerate beds that are undoubtedly equivalent to part, at least, of the Shoshone group, as typically developed in the Denver Basin, it seems to correspond to the Laramie according to King's definition.

Three coal beds are present in the "Laramie" where the entire formation is present. The lowest coal bed, which is usually the best, is regarded as the base of the formation and rests directly and conformably on the upper Montana sandstone. The second coal bed occurs about 187 feet above the lower coal in sec. 23, T. 8 S., R. 76 W., and about 175 feet above it in sec. 2, T. 9 S., R. 76 W. The upper coal bed lies about 221 feet above the middle coal in sec. 23, T. 8 S., R. 76 W., and 175 feet above it in sec. 2, T. 9 S., R. 76 W.

The formation attains its maximum thickness between secs. 23 and 2, mentioned above, where all three coal beds are present. About a mile south of sec. 2 the unconformity at the top of the "Laramie" cuts down into that formation, which within a few miles completely dies out, allowing the conglomerate to rest directly on the marine upper Montana sandstone. This condition prevails over the greater part of the coal field, and the "Laramie" is therefore absent in most places where it should normally occur. The details of its distribution are given in the following pages.

DISTRIBUTION.

The most northern exposure of coal in South Park is on Jefferson Hill, on the southern margin of T. 7 S., R. 75 W., about a mile north of the town of Jefferson. Here thin beds of coal were discovered in a well dug at Mr. Lilley's house, near the southeast corner of sec. 32. About 12 or 14 inches of coal is reported from a small abandoned prospect 300 feet west of this well. Samples of this coal, which had been dug about ten years, were shown to the writer by Mr. Lilley. The coal appeared to be of good quality, very hard and brilliant, and to show well-developed cubical cleavage. Coal smut was brought up by the drill from a horizon about 20 feet above the coal bed on which the prospect was driven. On Jefferson Hill the coal-bearing formation has a possible thickness of 250 feet.

In this township the position of the coal bed is entirely unknown except on Jefferson Hill. The location of the dotted line on the map that marks the hypothetical position of the coal bed is based largely on the supposition that the sill of porphyry which outcrops at Sheep Rock lies parallel to the sedimentary strata. It is possible, however, that this porphyry is intruded along a fault and that the coal bed is cut off by the porphyry and does not bend around toward the west in the manner indicated on the map. There appears to be no way of determining the position of the coal bed. Deep drilling would not be likely to strike it on account of the high dip of the rocks. South of the Jefferson Hill locality there is no exposure on the east limb of the syncline. The coal bed probably runs into the granite at some place in the southern part of T. 8 S., R. 75 E.

West of Jefferson Hill the north end of the syncline is not exposed. The coal bed may possibly encounter intrusive igneous rocks, as mentioned above, but more probably it lies concealed beneath the alluvium. The southeast corner of T. 7 S., R. 76 W., within which the coal must outcrop if present, is entirely covered by alluvium. The position of the bed indicated by the dotted line on the map is only a rough guess at the place where the coal may outcrop if present. This line may be as much as a mile too far northwest or half a mile too far southeast. It is given a curved form in order to make it more or less parallel with the outcrop of a deformed sill of igneous rock that is exposed conspicuously at Sheep Rock and other places. It is not likely that the coal bed remains beneath the conglomerate in this locality, because elsewhere in the park it has generally been removed by pre-Shoshone erosion, indicated by the unconformity mentioned above. Wherever measured in South Park the coal bed is not workable except near Como, in the southern part of T. 8 S., R. 76 W., and the northern part of T. 9 S., R. 76 W. As the rocks of the South

Park region are so deeply weathered that it is necessary to penetrate about 50 feet below the surface before reaching fresh coal, as the coal-bearing rocks in T. 7 S., R. 76 W., probably lie at angles of 45° to 90°, and as they are covered by an unknown amount of alluvium, possibly more than 100 feet thick, it seems improbable that coal will be found in this township, even if it is present.

In T. 8 S., R. 76 W., the "Laramie" formation is exposed in the old Como mine, about half a mile northwest of Como, and in several prospects in secs. 23, 26, and 35. It is also reported in a prospect in the NW. ¼ NE. ¼ sec. 19. The formation is absent in places, but where present ranges in thickness up to 425 feet, the variation being due to erosion which took place before the deposition of the overlying conglomerate of Shoshone age. The formation consists principally of sandstone and contains from one to three beds of coal.

It is said that at the old Como mine, in the NE. ¼ SE. ¼ sec. 29, T. 8 S., R. 76 W., which was abandoned in 1883, there was a pocket of coal 5 to 6 feet thick extending along the strike for about half a mile. At a distance of 300 feet down the slope a fault was encountered which brought sandstone against the coal. Operations were stopped at this fault. The writer believes that the downthrow is westward and that the fault is not large enough to repeat the outcrop of the coal bed. If this conclusion is correct, there must be a good bed of coal underlying the western margin of the SW. ¼ sec. 28. The conglomerate of the Shoshone group is exposed in a large well sunk by the Colorado and Southern Railway in the NE. ¼ SW. ¼ sec. 28. This occurrence substantiates the idea that coal could be found by drilling through the alluvium in the western part of sec. 28. The Como mine was inaccessible in 1908, being entirely caved in and filled with water. Many people in Como substantiated the report that the coal bed was 5 to 6 feet thick. Only one coal bed was reported, but it is believed from the distribution of the prospects that two beds may be present.

The following reference to the mine made by A. C. Peale[a] in 1873 partly corroborates this opinion:

> Near Lechner's ranch a shaft has been sunk about 30 feet deep, cutting a coal bed about 12 feet in thickness, with a dip of 45° NE. and a strike S. 45° E. The clay above the coal is about 6 inches and below the coal 10 inches thick. Below the lower clay is a sandstone, at the bottom of the shaft, and above the upper clay a bed of yellow soft sandstone. About 200 yards to the west another shaft has been sunk, exposing a bed of coal 6 feet thick. I am inclined to think there are two different coal beds here, though there may be but one. The slope underlaid by the coal strata extends up close to the sides of the mountain, and the surface is so covered with drift that it is only by means of these shafts that the Lignitic beds can be seen at all. A few fragments of deciduous leaves have been collected here, showing clearly that a portion of the Lignitic group, as seen on the east side of the mountain range, occurs here.

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[a] Seventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1873, p. 38.

In 1876 W. B. Potter[a] describes this mine as follows:

> The Lechner coal [is] worked by Mr. George W. Lechner, 1½ miles from Hamilton and 8 miles northeast of Fairplay, in the South Park. The seam is about 12 feet thick and the coal is of rather dull luster, uneven fracture, and exhibits a tendency to slack when exposed to the air and when heated. It burns freely without changing form and yields no coke.

On the north side of Tarryall Creek, in the NW. ¼ NE. ¼ sec. 19, T. 8 S., R. 76 W., Mr. Rogers showed the writer a prospect where a few inches (6 to 10?) of coal was found several years ago. This prospect had caved in and was filled with gravel from the wash of Tarryall Creek.

In the belt of coal extending through secs. 23, 26, and 35, T. 8 S., R. 76 W., three coal beds are present. Of these beds the lower one appears to be the best, but it is not workable at Mr. Arthur's prospect, in the NW. ¼ SE. ¼ sec. 23. At this place there is about 12 inches of bony coal at the horizon of the lower coal bed. In Mr. Dunbar's prospect, near the north quarter corner of sec. 26, about 2 feet of dirty coal and bone are exposed, according to the reports of people in Como. The coal contains many partings of carbonaceous shale, and is not workable. In a prospect in the SE. ¼ SW. ¼ sec. 26, sunk by Judge Foote, about a foot of clean coal and 3 to 4 inches of coal smut are reported at a depth of 45 feet. It is probable that this prospect was not deep enough to get through the zone of surface weathering, which is unusually deep in this region and has a marked influence in reducing the apparent thickness of the coal bed. At Mr. Arthur's second prospect, on the middle (?) bed, in the SE. ¼ SW. ¼ sec. 26, about 300 feet east of Judge Foote's prospect, 18 inches of clean coal was found at a depth of about 20 feet. The thickness increased to 22 inches at a depth of about 45 feet, remaining constant at this figure to the bottom of the prospect, which was about 60 feet deep at the time of the writer's visit. The coal, however, was not fresh even at that depth, although probably the bed had reached its full thickness. In spite of the high dip of the rocks, 45°, it is thought possible to work the coal bed for local use. A company known as the South Park Coal Company has been organized for this purpose by John Arthur, of Canon City, M. B. Burke, of Cripple Creek, and others.

The third or highest coal bed is very poorly developed, according to all reports, and is doubtless of no value in this township. It is said that at a prospect on this coal bed sunk about twenty years ago in the SW. ¼ SE. ¼ sec. 23, there was about 18 inches of dirty coal.

The rocks between the coal beds are not visible except at a few small exposures. In sec. 23 the stratigraphic interval between the lower and middle coal beds is 187 feet and that between the middle and upper coal beds is 221 feet.

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[a] The lignite coals of Colorado: Trans. Am. Inst. Min. Eng., vol. 5, 1877, pp. 365, 375.

In secs. 2 and 11, T. 9 S., R. 76 W., are located the old King mines of the Union Pacific Coal Company. At this place is the best development of coal known in the South Park region. In these mines, which were abandoned in 1893, three coal beds were worked, of which the upper two are said to have varied in thickness from 4 to 6 feet and the lower one from 7 to 40 feet. This lower bed had an average thickness of 7½ feet in the upper part of the mine and of 8 feet in the lower part. It was 8 feet thick at a depth of 2,000 feet, the maximum depth reached in mining. The thickness of 40 feet was apparently due to a large pocket about 500 feet in depth and 1,000 feet in length. It is thought to be the result of shearing and crumpling. Several pockets from 15 to 20 feet thick are reported as occurring in other parts of the mine. A section of the bed measured in 1908 is as follows:

Section of coal strata in S. ½ sec. 2, T. 9 S., R. 76 W.

	Ft.	In.
Upper coal not exposed.		
Rock, principally sandstone, not exposed	150	
Sandstone, massive	25	
Coal, middle	2	9
Sandstone, thin bedded	8	
Rock, principally sandstone, not exposed	167	
Coal, lower	7	
	359	9

The upper coal bed is said to be 4 feet thick, but this statement can not be verified. The lower coal bed rests on sandstone which contains upper Montana fossils. The intervals between the coal beds are variant, owing to changes in thickness of the beds due to differences in original deposition or to subsequent deformation and to the injection of small masses of igneous rock.

The condition of the King mines in 1902 has been described by R. C. Hills[a] as follows:

> Slopes No. 5 and No. 6 * * * turn out about 150 tons per day. * * * The inclination of the western outcrop ranges from 30° to 50°, being about 45° at No. 5 and 33° at No. 6, but less than this to the southward. Along the eastern border the Laramie outcrop is overlapped by what is probably the post-Laramie formation, which is found resting on the border of the granite hills bounding the district to the eastward,.
>
> The seam worked at No. 5 contains from 5 to 7 feet of coal in the lower bench and 2 feet in the upper bench, which is separated from the lower by from 8 inches to 3 feet of shale. At No. 6, which is about a mile south of No. 5, the seam worked is only 4½ feet thick. It is not certain that these openings are on the same seam, though this appears most probable. But the intrusion, both above and below the coal, of sheets of eruptive conglomerate which, a short distance south of No. 6, consolidate into one large body and thus determine the southern limit of the productive outcrop, throws some doubt on the identity of these seams until further extension of the respective workings shall have settled the question. Workable coal has been opened up some distance north of No. 5, but the locality is badly faulted. There is also another opening near the railway track

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[a] The coal fields of Colorado: Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 338.

[Como mine], on the opposite side of the Laramie area. The South Park coal cakes strongly, * * * but, all things considered, the district has less prospective value than any other independent area in the State.

Arthur Lakes[a] reports that the principal coal at the King mines is 7 feet thick, but that many faults hinder development. He states that in 1885 the production of No. 1 mine was 58,997 tons.

In the N. ½ sec. 2 the horizontal distance between the upper and lower coal beds is 600 feet. The dip is variant, ranging from 40° E. to 90°, and averaging probably about 45° E. The thickness of the rocks between the upper and lower coal beds is therefore about 425 feet, including a 50-foot intrusive sill of hornblende andesite and about 375 feet of sedimentary strata.

In the SW. ¼ NE. ¼ sec. 14, T. 9 S., R. 76 W., 4½ feet of clean coal is exposed in a coal prospect. This is thought to be the lower coal bed, but it may be the middle bed. In a prospect in the NW. ¼ SE. ¼ sec. 14 about 2 feet of coal was seen, but the bottom of the bed was concealed and could not be reached by the means at hand. At this place the coal bed is overlain by 8 feet of thin-bedded soft yellow sandstone, at the top of which is an erosional unconformity followed by conglomerate of the Shoshone group. As this is doubtless the lowest coal bed, it is evident that the upper beds and the rest of the "Laramie" formation had been removed by erosion before the deposition of the conglomerate. It is thought that south of this point the "Laramie" is entirely removed for several miles. In the SW. ¼ SE. ¼ sec. 14, three-eighths of a mile south of the last-mentioned locality, the conglomerate was found resting directly on the marine upper Montana sandstone (Fox Hills?). A similar observation was made in the NW. ¼ NW. ¼ sec. 35. No trace of coal could be found along the outcrop south of this point, although the débris ejected from prairie-dog holes was thoroughly examined and a prospecting drill was used about every half mile along the line where the "Laramie" should outcrop if present. There are no good exposures of the formation, owing to the covering of talus from the more resistant overlying conglomerate.

A few thin beds of coal were found in a prospect in the NE. ¼ NW. ¼ sec. 21. At this locality the rocks strike east and west and dip about 15° S. The "Laramie" formation is entirely covered by alluvium. It is probably cut off on the west by an intrusive mass of andesite porphyry. In secs. 29 and 32 the coal bed may possibly be present along the western margin of the andesite, as sandstone that resembles that at the top of the Montana group (Fox Hills? sandstone) is exposed near this margin. However, no trace of coal, carbonaceous shale, or sandstone of the "Laramie" formation could be found in these sections.

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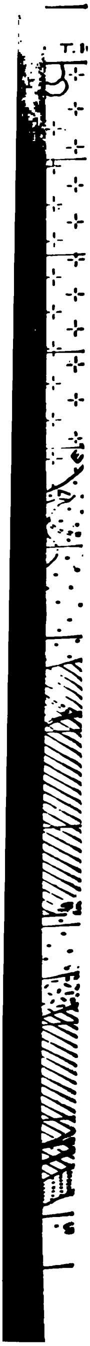
[a] The South Park coal field [Colorado]: Min. Rep., vol. 51, 1905, pp. 428-429.

No sign of coal was found in following the formation through T. 10 S., R. 76 W., although careful search was made for it by using a prospecting drill with which a depth of about 15 feet could be reached. In going southward the first sign of coal was obtained in the NW. ¼ SE. ¼ sec. 5, T. 11 S., R. 75 W., where the drill brought up some coal smut. Coal is exposed a short distance southwest of this point, in prospects in the southern part of the small syncline that runs through secs. 8, 17, 16, 21, and 28. The coal bed could not be accurately measured, but probably is less than a foot thick. The only place where the "Laramie" rocks are well exposed in this township is on a bluff in sec. 25, at the south end of the outcrop of rocks of the Shoshone group. Here there is about 50 feet of sandstone, barren of coal but containing layers of carbonaceous shale which may possibly belong to the "Laramie" formation. It rests conformably on marine upper Montana sandstone (Fox Hills?) and is unconformably overlain by conglomerate.

In a prospect near Myner's old house, in the NW. ¼ NE., ¼ sec. 28, 12 inches of coal is exposed. The coal is overlain and underlain by yellow sandstone. Fragments of coal were found on the dumps of old prospects in the NW. ¼ SE. ¼ and the SE. ¼ SW. ¼ sec. 21.

The coal zone is not exposed on the east limb of the syncline in T. 11 S., R. 75 W. The "Laramie" outcrop, if present, is concealed in places by débris from the ridge of conglomerate on the west and in places by débris from the granite hills on the east. On account of the apparent great quantity of débris it was thought useless to attempt to reach the coal with the short prospecting drill that was used in the field. The exact location of the coal horizon on the eastern limb of the syncline in this neighborhood is not known, but it must be very close to the position of the Montana-Shoshone boundary shown on the map and probably runs into the granite along the Elkhorn fault near the northern edge of T. 11 S.

The coal-bearing rocks may possibly be present on Reichenecker Ridge, but no evidence of them could be found, although the underlying marine upper Montana sandstones are exposed on the west side of the hill, and the overlying conglomerate of the Shoshone group is exposed on the east side of the hill. Between these two, on the summit and west slope, is a large mass of igneous rock consisting of andesite breccia and biotite porphyrite, the débris of which probably conceals any "Laramie" rocks that may be present. It is possible that the "Laramie" may be found on one side or the other of this igneous mass, either along the western foot of the ridge or east of the summit. Careful search during the reconnaissance of 1908 failed to reveal any trace of the formation on this ridge, except at the old prospect in the NE. ¼ NW. ¼ sec. 21, T. 9 S., R. 76 W., where a few thin beds of coal were found in yellow sandstone, probably of "Laramie" age. The



sandstone strikes nearly east and west and dips about 15° S. It is entirely concealed by alluvium except in the prospect. On the east it must terminate at the South Park fault, and on the west it is probably cut off by the intrusive mass of porphyry and andesite breccia mentioned above.

CHARACTER.

No fresh samples of the South Park coal could be obtained and consequently no chemical analyses were made during this examination. The only analyses available are two made a number of years ago when the mines of the field were in active operation. These analyses are as follows:

Analyses of coal samples from the South Park coal field, Colorado

	Proximate.				Ultimate.				
	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.
Lechner mine[a]	6.3	33.8	58.6	1.28	0.47	5.93	71.50	2.35	18.47
Mine No. 5[b]	7.2	38.7	49.4	4.70	.53	5.03	66.55	1.06	22.37

[a] Potter, W. B., Trans. Am. Inst. Min. Eng., vol. 5, 1877, p. 368.
[b] Hills, R. C., Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 362.

Although the quoted descriptions differ somewhat regarding the character of the coal, there can be little doubt that most of it is bituminous. It has well-developed cubical joints, is hard and lustrous, and gives a black streak. It is said that the coal cakes rather poorly in the beehive oven and that a large plant erected at Como about 1880 for the manufacture of coke did not obtain a good product. The coal stocks remarkably well, as shown by the fact that large lumps 6 inches or more in diameter were dug out of the dumps of the old mines, where they had been partly exposed to the weather for over ten years. These fragments were firm and hard, and although they broke readily along the joint planes when struck by the hammer, they did not crumble as a coal of poor grade certainly would after so long an exposure. When the Pishel test for determining coking coal is applied to these fragments they respond very poorly, the pulverized coal adhering but slightly to the sides of the mortar, but as weathering interferes greatly with the coking quality of coal, this can not be regarded as a fair test. Owing to the fact that all the mines had been abandoned many years before the writer's visit and were full of water or choked with débris, it was impossible to procure a fresh sample of coal for analysis. The outcrops of the coal are badly weathered, in places to depths of 50 feet or more, and they are covered by alluvium and talus to depths ranging from a few feet to several hundred feet. There are no natural exposures in the park.

CONCLUSION.

The coal of South Park is bituminous and of excellent quality for steaming purposes. The quantity available is unknown, and it seems unwise with the scanty evidence obtained during this examination to attempt any estimate of this quantity. In none of the prospects examined was the coal of satisfactory thickness. The future of the field is problematical and depends on the discovery of beds of workable thickness. Probably near the old King mines and possibly near the Como mine there is considerable coal which was not removed by the early operations. This can be mined if sufficient care is taken to avoid dangerous flows of water from the adjacent old mines, all of which are completely flooded at the present time.

THE COLORADO SPRINGS COAL FIELD, COLORADO.

By Marcus I. Goldman.

INTRODUCTION.

LOCATION AND EXTENT.

The part of the Colorado Springs coal field described in this report lies in El Paso County, Colo. Its southern limit is the outcrop of the coal-bearing sandstone and shale which extends from the region just north of Colorado Springs in a direction a little south of east to T. 15 S., R. 62 W. The northern limit is indeterminate, for the coal-bearing rocks pass under cover in that direction and all development and exploration are less than a mile back from the outcrop; hence statements regarding the presence and condition of the coal at a greater distance are only assumptions. The western limit of the field is also indeterminate, but may be taken as the locality in T. 13 S., R. 67 W., at which the coal-bearing beds pass under the cover of gravel adjacent to the mountains. Coal, however, is not exposed west of the Monument Valley mine, in sec. 11, T. 13 S., R. 67 W. In the opposite direction the outcrop of the coal zone can be traced (with interruptions due to a cover of soil) in a direction somewhat south of east for about 40 miles.[a]

The coal outcrop was examined with considerable care, but in the area to the north a much less detailed examination was made.

From its outcrop, as described above, the coal dips gently to the northeast, generally at about 3° to 5° with local increases up to 8° or 10°. From the low dips it is believed that the coal-bearing strata extend under the divide between Platte and Arkansas rivers, coming to the surface again a little south of Denver. On account of this connection the Colorado Springs field is regarded as part of the larger Denver coal region. It also seems probable that the coal-bearing rocks originally continued far to the south, but they have been carried away by erosion, leaving only isolated fields along the base of the Front Range.

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[a] Hills, R. C., Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, p. 332. Storrs, L. S., Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, p. 432.

The Colorado Springs field lies 18 or 20 miles south of the Platte-Arkansas divide, which runs eastward from Palmer Lake, and its general slope is toward the south. The largest stream in the field and the only one that is permanent is Monument Creek, near the western edge. The valley of this stream forms one of the principal lines of communication between Denver and Colorado Springs, and it is utilized by the Denver and Rio Grande and the Atchison, Topeka and Santa Fe railroads.

For some distance east of Palmer Lake the divide is somewhat rough, so that the Colorado and Southern Railroad, which follows a plains route from Colorado Springs to Denver, is obliged to make a detour of about 15 miles in order to find a satisfactory grade. The only other obstacle to lines of communication across the plains is Corral Bluffs, about 12 miles east of Colorado Springs.

South of Colorado Springs the valley of Fountain Creek forms the most convenient line of communication with Pueblo, though the country is so open that roads and railroads could be built in almost any direction.

Communication with Cripple Creek through the mountains to the west is of course difficult, yet that town is entered by two railroads from Colorado Springs. The Colorado Midland ascends slowly through Ute Pass, and the Colorado Springs and Cripple Creek District (Colorado and Southern) plunges directly into the mountains through North Cheyenne Canyon.

PREVIOUS GEOLOGIC STUDIES.

The two reports that contain the fullest information on this field are those of A. C. Peale[a] and R. C. Hills.[b]

At the time Peale's report was written there were no mines of any commercial importance. One known as the Gehrung mine, believed to have been situated on the east bank of Monument Creek, a little south of the present Carlton mine, had not proved to be very successful and the old Franceville mine was not yet open, though Peale states that he went out with Mr. France to see the coal, then as now exposed in a stream course at the west edge of sec. 19, T. 14 S., R. 64 W. Peale concerned himself mainly with the geology of the foothills and mountains. At the time Hills made his report mining was more extensive, the Franceville and McFerran mines had been well developed, and the extent of the field was understood, though the large mines north of Colorado Springs had not yet been opened.

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[a] Ann. Rept. U. S. Geol. and Geog. Survey Terr. for 1873, 1874, pp. 193–270.

[b] Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, pp. 319–365.

GENERAL GEOLOGY.

For a fuller account of the general geology of this region the reader is referred to the forthcoming Colorado Springs folio, which is being prepared by G. I. Finlay. For present purposes it will be sufficient to outline the general geology of the beds associated with coal, which was worked out by Professor Finlay and the writer jointly. The discussion begins with the Pierre shale.

STRATIGRAPHY.

PIERRE SHALE.

The Pierre shale underlies the entire coal field and outcrops in an extensive region to the south and east of Colorado Springs. It is a dark-gray clay shale which in the vicinity of Colorado Springs is approximately 3,000 feet thick. The monotony of this great mass of shale is relieved by the local occurrence of concretions composed of carbonate of lime and carbonate of iron, which weather to small fragments of a rusty brown color. The Pierre shale also contains lenses of gray limestone which because of their relative hardness in places form prominent conical hills known as "tepee buttes." The Pierre shale grades upward by an increasing abundance of sand into the overlying Fox Hills sandstone.

FOX HILLS SANDSTONE.

In places where it has been impregnated with lime the Fox Hills sandstone is of a deep reddish brown color, but the upper portion, near the contact with the Laramie, is generally a light-yellow, nearly pure quartz sandstone. Calcareous sandstone concretions from a few inches up to 3 or 4 feet in diameter, and generally with a fossil imprint of a seaweed at the center, are common in the sandstone.

In most places it is not possible to draw a sharp line between the sandstone at the base of the Laramie and that at the top of the Fox Hills. The latter is typically somewhat micaceous, whereas the former contains minute grains of black chert and no mica. Generally, however, there is no sharp distinction between them. The only exposure in which there seems to be a definite line between the Fox Hills and Laramie is that at Crows Roost, on Black Squirrel Creek. Here the Laramie also is concretionary, but there is a distinct difference in bedding, texture, and character of contained concretions between the two formations.

LARAMIE FORMATION.

Above the Fox Hills sandstone lie the coal-bearing rocks of Laramie age. These may be divided into two members—a lower including several massive sandstone beds and three of the most important coal beds of the field, and an upper composed of clay shale, sandy shale, and some sandstone with poorly developed coal beds.

The best exposure of the sandy, coal-bearing member is in Popes Bluff, where the base of the formation is composed of a massive sandstone from 40 to 100 feet thick, but not sharply defined from the underlying Fox Hills. The upper part of the sandstone member of the Laramie gives way gradually, toward the east, to shale with thin beds of calcareous and ferruginous sandstone about 250 feet thick. In the western part of the field the sandy member is about 200 feet thick.

The shaly member covers more than a square mile west of the Pikeview mine and in section it is well exposed on the slope below Pulpit Rock, where its thickness is about 150 feet.

ROCKS ABOVE THE LARAMIE.

Paleontologic evidence, mainly that of fossil leaves, is at present too incomplete to permit definite correlation of the formations overlying the Laramie. In the following descriptions attention is drawn to the lithologic similarities of these rocks to formations in the Denver region, but the subdivision and naming of the beds is left to the future.

Conglomerate.—In some parts of the field the shaly part of the Laramie is overlain by a conglomerate containing some pebbles of sedimentary rocks but mainly of rusty quartz. The pebbles range from 1 inch to 2 inches in diameter. In places a very pure, hard white quartzose sandstone takes the place of the conglomerate. The maximum known thickness of the bed is about 30 feet, in an exposure on Monument Creek back of the Curtis mine, a few hundred feet west of the Cragmore sanitarium. The lithologic similarity of this bed to some parts of the Arapahoe formation in the Denver Basin is apparent.

Andesitic material.—The conglomerate is overlain by beds of andesitic material, which in lithologic composition is similar to the Denver formation. Where exposed in natural outcrop these rocks are mainly yellow, yellowish green, and cream colored, with a few beds 1 to 2 feet thick of black, leaf-bearing coaly shale and of limonite, generally not more than 1 foot thick and in places full of plant fragments. Most of this rock is very soft, so that material from the upper beds washes down over those below, covering the contacts. In places there is a pebble bed composed of well-rounded fragments, averaging half an inch in diameter, of andesite in a matrix apparently of the same material.

The most complete exposures of the beds containing andesitic material were observed in the bluffs underlying Pulpit Rock on the west bank of Monument Creek, opposite Pikeview (see section 22, p. 328), and along the west fork of Jimmy Camp Creek south of the Richfield

Springs ranch and just north of the county road. The pebble bed is present in the Pulpit Rock section, where it is about 18 feet thick.

The average thickness of the beds of andesitic material is about 125 feet.

Arkose.—Beds of arkose lie unconformably upon the andesitic material and overlap the coal-bearing sandstone in the southeast corner of sec. 6, T. 13 S., R. 67 W. The arkose has two phases—(1) coarse arkose near the mountains, some sandstone, and clay containing coarse quartz grains; (2) fine-grained, very micaceous sandstone. Both phases are very irregularly bedded, and most of the lithologic units are of small horizontal extent. An exception to this discontinuity is a bed of conglomerate within 10 feet of the base. This was not observed near the mountains, but is well exposed on Jimmy Camp Creek and was found also in a stream channel just east of the Franceville schoolhouse. The pebbles range from half an inch to 1 inch in diameter and are siliceous, brightly colored, and rounded, and have glossy surfaces. The surface of the road beyond the first crossing of Jimmy Camp Creek south of the Richfield Springs ranch is strewn with these pebbles, but the bed could not be found in place.

The total thickness of the arkose has nowhere been determined. It would, in fact, necessarily be variant on account of the irregular deposition and meager horizontal extent of the material. From this irregularity it is probable that the apparently successive beds encountered in crossing the formation on a flat or gently sloping surface may be equivalent instead of consecutive. The only way to obtain reliable measurements of the beds would be by drilling at places where the formation is well exposed.

The greatest thickness measured in surface exposures of the arkose is about 200 feet in Austin Bluffs and 300 to 400 feet in Corral Bluffs. The total thickness, however, is believed to be still greater.

Gravel.—Covering all the formations near the mountains is gravel, mainly of granite débris. The boundaries of the terraces covered by the gravel have been mapped only where they cross the coal-bearing formation.

STRUCTURE.

The geologic structure of the region adjacent to the coal outcrop is very simple. From the southwesternmost point of Popes Bluff to the east end of the strip examined the strike seems to be uniformly N. 50° W., and the dip ranges from 2° to 10° NE. The most marked variation from this general structure is in the northwestern part of Popes Bluff, where, as the coal-bearing sandstone approaches the mountains, it is turned up steeply (40°–50°) and the strike is more nearly parallel to the trend of the mountains (N. 30° W.). The two most marked variations in dip are the steep dip of 10° on Jimmy Camp Creek and the flattening around Franceville.

COAL.

DETAILED SECTIONS.

The best opportunity for the study of the coal beds and of their relation to each other is afforded in Popes Bluff and adjacent exposures on the west side of Monument Creek. Numerous sections were made here, as well as at other places along the outcrop, and the most representative of these are given on the following pages. The facts shown by these sections are discussed on pages 332–335.

Sections of coal beds and coal-bearing rocks in Colorado Springs field.

[Numbers of sections correspond to those given on Pl. XVII.]

1. Monument Valley mine, sec. 11, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	30	
Sandstone, ferruginous		6
Interval, mainly shale	57	
Sandstone	2	6
Interval, mainly shale.[a]		
Clay, carbonaceous Coal Coal, sandy } bed B	 2	6 7

2. Abandoned mine, sec. 14, T. 13 S., R. 67 W.

a. Section at mine mouth.

	Ft.	in.
Clay, pink, containing fossil plants	3	
Clay	1	
Coal Coal, sandy } bed B	1 1	10
Sandstone, massive.		
	3	10

b. Section 30 feet down slope.

	Ft.	in.
Clay, carbonaceous Coal Coal, sandy } bed B	 2	8 10
	3	6

70 feet down the slope the coal bed is 2 feet thick.

3. Popes Bluffs, sec. 14, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	20	
Interval, probably shale	9	
Sand, nodular, ferruginous	2	
Interval, mainly shale	50	
Sand, containing nodular concretions of iron	1	
Shales, gray and carbonaceous	10	
Sand, with ferruginous nodules and impressions of plants	1	
Sandstone, soft, ferruginous	2	
Clay, gray	1	
Shale, carbonaceous	1	6
Sandstone, ferruginous		6

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[a] Thickness not given in original notes.

		Ft.	in.
Sandstone, soft, yellow		4	
Shale, greenish		1	6
Shale, carbonaceous		3	6
Sandstone		3	
Coal			2
Shale, carbonaceous		1	
Clay, greenish		6	6
Shale, carbonaceous		1	6
Clay, sandy		3	
Shale, carbonaceous	bed B		2
Coal		2	
Coal, bony			5
Coal, sandy			5
Sandstone		19	
Conglomerate		2	
Shaly coal			6
Sandstone		1	6
Coal, sandy, bed A			7
Sandstone, gray, massive		15	
		163	9

4. Popes Bluffs, sec. 23, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)	15	
Interval, mainly shale	60	
Shale, carbonaceous	4	
Sandstone, argillaceous	4	6
Shale	8	
Shale, carbonaceous	1	
Sandstone	1	6
Shale, carbonaceous	3	
Coal, bed B		10
Sandstone	23	
Shale, sandy	2	6
Shale, carbonaceous		2
Sandstone	2	10
Coal, sandy, bed A	1	
Sandstone	3	
Interval, probably sandstone	12	
Sandstone, gray	18	
	160	4

5. Coal prospect on east side of Popes Bluffs, sec. 23, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone		5	
Clay		4	
Coal	bed B		11
Clay and bone			8
Coal		1	6
		12	1

6. Popes Bluffs, sec. 23, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)		20	
Shale, gray		3	
Shale, carbonaceous		18	
Sandstone		30	
Shale, carbonaceous		12	
Sandstone, yellow, shaly		2	
Shales, light gray and brown, with coal bands 3 to 4 inches thick		45	
Sandstone, soft		2	
Shale, carbonaceous	bed B	1	6
Coal		2	6
Sand, coaly			10
Sandstone, massive, gray		25	
Shale, carbonaceous, coal, bed A (?)		4	
Sandstone, gray		1	
		166	10

7. Popes Bluffs, sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)		25	
Shale, greenish		25	
Sandstone, soft, argillaceous		12	
Shale, carbonaceous		2	
Sandstone		3	
Shale, carbonaceous		5	
Shale, greenish		8	
Sandstone		3	
Shale, carbonaceous		5	
Sandstone, ferruginous			6
Shale, gray		3	6
Sandstone	bed B	15	
Coal		1	
Sand, soft, coaly		1	
Iron nodules			4
Sandstone, massive, gray		25	
Shale, brown, carbonaceous, coal, bed A(?)		3	
Shale, sandy		1	
Sandstone, gray, massive		40	
Sandstone, greenish		40	
		218	4

8. Sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie).			
Interval		34	
Coal		1	4
Shale		8	
Sandstone		14	
Shale, carbonaceous		2	
Sandstone and sandy shale		37	
Sandstone, massive, gray		13	
Shale, carbonaceous	bed A	1	6
Coal			3
Shale, carbonaceous			6
Coal		1	7
Shale, brown, sandy			6
Sandstone.			
		113	8

9. Sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie).			
Interval, mostly shale		12	
Coal		1	6
Shale and sandstone		28	
Shale		5	
Coal, bed C			11
		47	5

10. Sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone		3	
Coal			6
Shale, carbonaceous		2	1
Clay		8	
Coal	bed C	2	6
Shale, carbonaceous			6
Clay			6
Sandstone, yellow		2	6
Shale, gray			1
Sandstone, soft, yellow			5
Shale, light gray with coal intrusions		3	
Sandstone, gray		16	
Coal bed B, not well exposed.			
		39	1

11. Sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Coal			6
Shale, carbonaceous		2	
Clay		1	6
Sandstone		6	
Coal	bed C	2	4
Shale, carbonaceous			6
Clay.			
		12	10

Below this section coal bed B is exposed with a thickness of 8 inches.

12. Mouth of prospect in sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Shale, carbonaceous	bed C	2	6
Coal			7
Bone			2
Coal, bony			5
Shale, carbonaceous		1	2
Clay.			
		4	10

13. Sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone (uppermost bed of lower division of the Laramie)		20	
Shale, gray		25	
Sandstone, soft		18	
Shale, gray		8	
Shale, carbonaceous		3	
Coal			2
Shale, carbonaceous		5	
Shale, gray		3	
Sandstone, massive, yellowish, gray		10	
Bone	bed C		5
Coal		1	10
Bone			4

		Ft.	in.
Clay		4	
Sandstone		20	
Sandstone		25	
Shale		2	
Shale, carbonaceous		1	6
Shale, containing some coal	bed B	1	
Coal			3
Bone			3
Shale		2	
		150	9

14. Coal prospect in sec. 24, T. 13 S., R. 67 W.

		Ft.	in.
Sandstone.			
Coal, bed C			3
Shale, brown, carbonaceous		2	
Clay, green		3	
Sandstone		30	
Coal, bony	bed B		7
Clay, gray		1	5
Coal, hard, bright, conchoidal		1	1
Clay		1	11+
		40	3

The prospect slope, about 200 feet long, was driven in mostly on coal bed B, but at the end of the slope the bed is in about the same condition as where it was first struck.

15. Yards of Colorado Brick and Artificial Stone Company, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Shale, greenish yellow		4	
Sandstone, soft, ferruginous		5	
Shale, gray, with carbonaceous and ferruginous partings		7	
Sandstone, soft, white, massive		30	
Clay		3	
Sandstone, soft, gray, massive		17	
Shale, with yellow gypsiferous sandy layer in middle		30	
Coal, bed C		1	6
Clay		1	6
Sandstone, gray, massive		35	
Shale, carbonaceous	bed B	1	6
Coal			2
Shale, carbonaceous			10
Shale			6
Sandstone, soft, yellow, with shaly layers		25	
Shale, gray		3	
Coal	bed A		6
Coal, sandy			9
Sandstone.			
		166	3

16. West bluff along which road runs, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone.			
Coal, including about 2 inches of bone near middle	bed B		11
Shale, carbonaceous		3	
Sandstone		26	
Coal, bed A (?)		2	6
Shale, brown.			
		32	5

Coal bed A varies from 1 foot 10 inches to 3 feet in thickness.

17. Coal beds in upper part of formation in sec. 14, T. 13 S., R. 67 W.

	Ft.	in.
Limonite, concretionary	2	
Shale, with limonite concretions	20	
Sandstone	1	6
Shale (?)	10	
Shale, greenish gray	5	
Shale, carbonaceous	3	
Coal	2	2
Shale, carbonaceous	5	
Sandstone		5
Shale (?)	5	
Shale, sandy	5	
Shale (?)	6	
Sandstone, gray	10	
Sandstone, ferruginous	1	6
Sandstone, cross-bedded	20	
Sandstone, massive	25	
Sandstone, argillaceous	5	
Sandstone, ferruginous	2	6
Shale	8	
Sandstone	18	
	155	1

18. Air shaft of Neer mine, sec. 13, T. 13 S., R. 67 W.

	Ft.	in.
Sandstone, massive	100	
Clay, sandy	2	2
Coal, bed C (?)		½
Shale, carbonaceous	1	6
Clay, sandy	35	
Sandstone, with coal bands, coal bed B (?)	2	
Sandstone, massive	30	
Coal, bed A	3	
Coal bed A is the one worked in this mine.	173	8½

19. Coal prospect in sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, massive		13	
Shale, carbonaceous with coal lenses	bed B		3
Coal			7
Bone			10
Clay		25	
Coal, bed A.		39	8

0. Upper part of coal-bearing formation west of Carlton mine, NE. ¼ sec. 13, T. 13 S., R. 67 W.

	Ft.	in.
Shale, gray		6
Coal	1	4
Shale, carbonaceous	1	
Clay, gray	1	
Shale, gray (?)	12	
Shale, carbonaceous with traces of coal		6
Coal	1	
Shale, carbonaceous	1	

	Ft.	in.
Clay, gray	2	
Coal		7
Shale, carbonaceous	3	
	23	11

The middle coal bed in this section varies from 6 to 18 inches within a horizo[illegible]l distance of 20 feet. The coal beds are probably lenticular and irregular, as they not show in the section back of the Carlton mine.

21. Carlton mine, sec. 18, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, soft.			
Coal, laminated and bony, with 2 inches of sandstone near base	bed A		10
Coal		3	2
Coal, "siliceous," bony		1	
Coal		3	8
Coal, bony			5
		9	1

22. West side of Pulpit Rock, sec. 17, T. 13 S., R. 66 W.

	Ft.	in.
Arkose.		
Clay, gray		6
Sandstone, gray (fossils)	4	
Shale, gray	1	6
Clay, purplish brown	2	
Shale, carbonaceous, and gray sandstone	8	
Sandstone, argillaceous	8	
Clay, brownish gray (fossils)	2	
Sandstone, quartzose	7	
Shale, carbonaceous	1	
Tuffs, gray and greenish yellow, with carbonaceous shale	65	
Conglomerate with pebbles of andesite	18	
Tuffs, gray and greenish yellow, with carbonaceous shale	46	
Interval, probably composed of tuff	15	
Clay and argillaceous sand (fossils)	125	
Sandstone, soft, white, with carbonaceous bands	50	
Sandstone, massive, yellow	3	
Clay, sandy	2	
Sandstone, argillaceous	2	
Clay, gray, sandy	3	
Clay, gray	1	6
Coal and clay, interlaminated		8
Clay, gray, sandy	5	
	370	2

The thicknesses given in this section are only approximate, as the dips are sligh and the section was measured along a gently inclined surface.

23. East bank of Monument Creek, opposite old Williams mine, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, massive, yellow.			
Shale		15	
Shale, carbonaceous	bed A		6
Bone			5
Coal		1	
Coal, impure		1	2
Shale, carbonaceous		1	2
Clay, greenish gray.			
		19	3

Gully on east bank of Monument Creek east of Pikeview station, sec. 19, T. 13 S., R. 66 W.

		Ft.	in.
Sandstone, soft, white		5	
Coal, sandy			2
Clay, sandy		3	
Interval concealed		2	
Sandstone, massive		15	
Clay, sandy		13	
Shale, carbonaceous			3
Clay, sandy			6
Shale, green		20	
Shale, carbonaceous	bed C (?)	2	
Coal			10
Shale, carbonaceous		1	4
Shale, green		2	
Interval, probably shale		3	
Sandstone, massive		17	
Coal	bed B		6
Shale, carbonaceous		1	
Sandstone		23	
Shale, mostly carbonaceous	bed A	6	
Coal		4	
Shale, carbonaceous		1(?)	
Coal			3
Clay		3	1
Shale, greenish		6	
Bone			1
Shale, carbonaceous		2	5
Bone			4
Coal, bed A		1	2
Sandstone		46	
		176	3

27. Curtis mine, sec. 29, T. 13 S., R. 66 W.

		Ft.	in.
Shale		3	
Shale, sand, and clay		5	
Sandstone, massive		13	
Shale			6
Clay, gray			9
Bone	bed A		8
Bone, with layers of coal		2	2
Coal, bony		1	6
Coal		12	9
Clay.			
		39	4

32. Sec. 12, T. 14 S., R. 66 W.

		Ft.	in.
Shale, carbonaceous, resembling coal; probably represents a coal bed			5
Shale, in places sandy		4	
Sandstone, massive, soft, ferruginous		1	6
Shale, sandy in upper part		4	
Clay, sandy			3
Shale, carbonaceous	bed A (?)		3
Coal			10
Shale, carbonaceous		1	

	Ft.	in.
Sandstone, massive, argillaceous	3	6
Shale, dark gray	4	
Sandstone, ferruginous	2	4
Sandstone, soft, yellow, fine grained, quartzose	11	
Shale, gray	2	4
Shale, sandy, ferruginous	2	4
Sandstone	40	
	77	9

33. Sec. 19, T. 14 S., R. 64 W.

	Ft.	in
Coal, not fully exposed, bed B.		
Shale, yellow, sandy	1	6
Sandstone	1	10
Shale, gray	3	
Sandstone	2	6
Clay and shale (fossils)	4	
Coal, bottom not exposed, bed A	7	
	19	10

35. Davies mine, sec. 29, T. 14 S., R. 64 W.

	Ft.	in.
Coal, bony		5
Shale, carbonaceous		6
Clay	2	
Sandstone, yellow, massive	10	
Clay, carbonaceous		3
Coal	1	
Bone		5
Clay, gray	5	
Coal } bed A	1	1
Coal, bony } bed A	1	3
Coal } bed A	2	4
Clay		2
	24	5

36. Stream bank in SE. ¼ sec. 32, T. 14 S., R. 64 W.

	Ft.	in.
Coal		4
Shale, sandy	15	
Coal		4
Shale, sandy	20	
Sandstone, soft, gray	2	
Clay, gray		6
Shale	1	
Coal	1	2
Shale, carbonaceous	2+	
	42	4+

37. Along stream channel just south of Banties ranch, sec. 20, T. 15 S., R. 63 W.

	Ft.	in.
Sandstone.		
Clay, carbonaceous		3
Shale, gray		8
Coal	1	
Clay, gray		½
Sandstone	5	
Shale, gray	5	
	11	11½

38. Jimmy Camp Creek; upper part measured due east from Richfield Springs ranch and lower part in sec. 15, T. 14 S., R. 65 W.

		Ft.	In.
1.	Sandstone, soft, argillaceous (fossils)	1	
2.	Sandstone, massive, cross-bedded, tuffaceous	10	
3.	Shale, gray	1	
4.	Shale, carbonaceous	1	
5.	Shale, gray	5	6
6.	Shale, gray, and yellow sandstone	102	
7.	Shale, carbonaceous		2
8.	Shale, gray		4
9.	Shale, carbonaceous		½
9½.	Coal		½
10.	Clay		½
11.	Coal		4½
12.	Interval, covered	550	
13.	Arkose, quartz and feldspar	3	
14.	Concealed	90	
15.	Shale, sandy, yellow	37	
16.	Shale, carbonaceous	1	
17.	Tuff	41	
18.	Shale, containing some coal		4
19.	Tuff	5	
20.	Shale, black, carbonaceous	1	
21.	Tuff	20	
22.	Sandstone, ferruginous (fossils)		10
23.	Tuff	11	6
24.	Tuffs, yellow and purple	7	
25.	Shale	33	
26.	Sandstone, ferruginous	2	
27.	Shale	14	
28.	Sandstone, massive, soft, argillaceous	4	6
29.	Shale, yellow and dark gray	22	
30.	Sandstone, calcareous	2	
31.	Shale	4	
32.	Sandstone, soft	27	
33.	Shale, with ferruginous layers	2	
34.	Sandstone, soft	2	4
35.	Shale, sandy	7	
36.	Interval, not measurable on account of local increase of dip and change of strike; estimated	10	
37.	Shale, carbonaceous		10
38.	Coal	2	4
39.	Concealed	36	
40.	Sandstone, ferruginous	2	
41.	Shale	2	
42.	Shale, carbonaceous		10
43.	Shale, green	17	6
44.	Sandstone	4	6
45.	Shale, carbonaceous	1	6
46.	Clay	1	
47.	Coal, bed A (?), burned and underlain by coaly sandstone	6	
48.	Sandstone, shaly	8	

	Ft.	in.
49. Sandstone, gray, massive	24	
50. Sandstone, gray, ferruginous	6	
51. Sandstone	4	
52. Sandstone, soft, gray, quartzose	27	
53. Interval, not measurable but estimated	25	
54. Conglomerate, ferruginous	2	
55. Shale, gray	2	
56. Conglomerate, ferruginous	2	
57. Sandstone, concretionary	20	
58. Sandstone, soft (fossils)	25	
59. Sandstone, soft, yellow	25	
60. Shale, light gray.		
	1,263	6

From an inspection of these sections it is evident that there are three more or less well defined coal beds. These have been lettered, beginning at the bottom, A, B, and C. Bed A, which is the principal bed, is not well developed west of Monument Creek. At the most easterly of these places (section 15), the coal shows its greatest thickness of 1 foot 3 inches. There seems to be little doubt, however, from its position in the section that the carbonaceous shale and coaly sand shown in many sections and marked coal A is the impure marginal portion of the coal bed.

The outcrop of coal bed B where it is 2 feet or more thick is shown on the map (Pl. XVII) and its position in the column is indicated in several sections. That the coal which has been prospected and developed along the west face of Pikeview Bluffs is bed B and not bed A seems evident from its position in the sections—from its relation, for instance, to the topmost of the three sandstones that are so well developed in this part of the field.

Although the map shows that a third bed, called coal C, reaches a thickness of 2 feet or more over a small extent of its outcrop in the area of the bluffs under discussion, yet it may be seen from the sections that it is not a persistent bed but rather a local development of coal at different horizons within a shaly band of varying thickness lying between the middle and upper beds of sandstone.

There is little reason to expect that individual coal and sandstone beds in this section could be correlated with sandstone and coal beds in the vicinity of Denver; yet, as a matter of fact, the similarity between the coal-bearing rocks in the two fields is remarkable. Thus, in the western part of the Colorado Springs field and in the Denver field there is "a series of basal sandstones up to 200 feet in thickness."[a] Above this series in both fields occurs an argillaceous formation, but in the Denver field this is 400 to 1,000 feet thick, whereas in the Colorado Springs field it is only about 150 feet thick. In both fields the sandstone is divisible into three beds with intermediate beds of coal and shale. The similarity is shown in figure 3.

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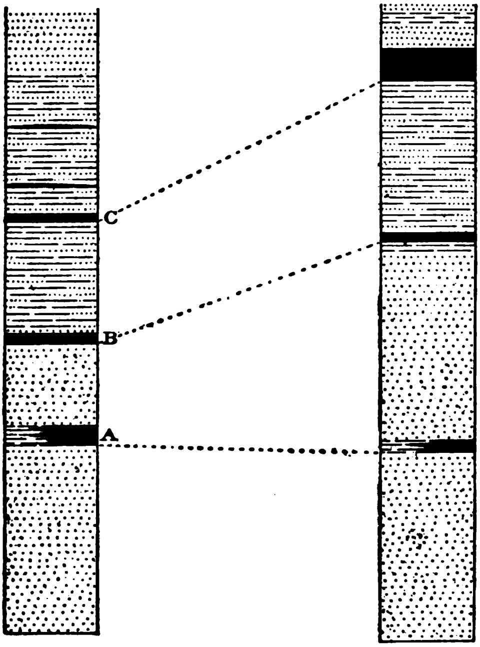
[a] Emmons, S. F., Mon. U. S. Geol. Survey, vol. 27, 1896, p. 28.

Between the place where section 7 was measured and Monument Creek a workable though varying thickness of coal outcrops in the banks of the streams. There is no means of determining which coal bed is worked in the Carlton mine, but from the more extensive development of coal A it is believed to be that bed. If this interpretation is correct, however, the thickening is local, for along Monument Creek to the south bed A, as shown in section 6, contains little coal. Coal bed A is of workable thickness in the Williamsville mine, expands to a maximum of 14 feet in and near the Curtis mine, and, according to report, thins to less than 3 feet in the Enterprise mine.



Section at Popes' Bluffs
Colorado Springs field

Section at Marshall, Denver Basin
(Mon. U.S.G.S. No. XXVII p.346)

Scale 1 inch=60 feet

FIGURE 3.—Sections showing similarity in the arrangement of the coal-bearing part of the Laramie formation in the Colorado Springs field and in the Denver Basin.

Coal sections 25 to 31 (Williamsville to Tudor) show in greater detail the variations in this coal bed. A bed of impure coaly material about a foot thick at both ends of this thick body of coal is well brought out in these sections. In places this bed is almost pure clay and attains a thickness of 2 feet, but benches of coal about 3 feet thick remain above and below it. It is well to bear this in mind in developing the coal of this region and to test occasionally with drill holes through the roof and floor for overlying or underlying benches of coal.

From an exposure on Sand Creek about half a mile southeast of the Enterprise mine (section 32) to the bluffs on Jimmy Camp Creek no exposure of coal could be found, as the rocks are nearly covered by soil. On Jimmy Camp Creek most of the coal along the outcrop has been burned. From records of the old McFerran mine, however, the coal bed is known to have averaged about 6 feet in thickness. A few hundred feet south of the road on the east bank of the creek, in sec. 18, T. 14 S., R. 65 W., an upper coal bed shows but is not well exposed. Here 2 feet 4 inches of coal was measured without reaching the bottom. This bed is about 65 feet above coal bed A and is therefore in the position of coal bed C.

In secs. 14 and 15, T. 14 S., R. 65 W., there are numerous exposures of coal. Farther east, however, little evidence of the coal bed can be seen until the old Franceville slope is reached, and the first good section of it is found in the creek bank just north of the highway bridge at the west edge of sec. 19, T. 14 S., R. 64 W. Here 7 feet of coal is exposed without showing the bottom. Coal section 35 represents the coal bed in the Davies mine and shows that the coal here is thinner. In sec. 32, T. 14 S., R. 64 W., the coal bed is thinner still and where the outcrop crosses the east line of sec. 5, T. 15 S., R. 64 W., the coal has probably a thickness of only a few inches. More noteworthy than the outcrop of coal A in this strip is the occurrence of a group of upper coal beds (perhaps coal C) in the creek in the NE. ¼ sec. 5. From this point to the east end of the field the only exposure of coal that could be found is a bed 1 foot thick in sec. 20, T. 15 S., R. 63 W. (See section 37.) On Black Squirrel Creek south of Crows Roost ranch the beds at the horizon of the coal are fairly well exposed, yet no trace of a coal bed could be found. It seems probable, therefore, that along the outcrop in T. 15 S., Rs. 62, 63, and 64 W., there is no workable coal.

Coal in the shaly member of the Laramie is known in only two places in the field, both near the west end, in secs. 13 and 14, T. 13 S., R. 67 W. (See sections 17 and 20.) At both places the coal has been prospected but the openings are caved. The coal appears bright and clean, but the beds are of varying thickness and apparently of slight horizontal extent. On account of soil covering it was not possible to determine whether the two outcrops are connected.

In this connection Emmons's comment on the coals of the shaly Laramie in the Denver Basin may be noted.[a] "Coal seams have also been found in the upper clayey division, but the coals are lignites [subbituminous in the present classification], with higher percentages of water and of inferior economic value."

Coaly shale occurs in the formation next above the Laramie, but so far as known the thickness of the coal beds in this formation is so small as to make them entirely negligible.

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[a] Emmons, S. F., Mon. U. S. Geol. Survey, vol. 27, 1896, p. 29.

In the andesitic beds dark-brown shale full of leaf fragments is found and here and there it contains some coal. This is shown in section 38 from No. 14 to No. 24, inclusive.

Above this, in the arkosic rocks along the east bank of Jimmy Camp Creek, east and a little southeast from the Richfield Springs ranch, several small coal beds occur as shown in section 38 from No. 2 to No. 12, inclusive.

These sections show no coal of any practical importance, nor were prospects on coals in the arkosic or andesitic beds found in the part of the field represented in the accompanying map. The thickest bed of coal in the upper formations, as reported in well records, is 10 inches thick, but recently thick beds have been reported several miles north and east of Falcon.

The following list gives the location of the places where sections were measured and samples taken for analysis. The numbers correspond to those of the sections given above and also to those used on Plate XVII.

1. Monument Valley mine, sec. 11, T. 13 S., R. 67 W. Coal bed B; analysis No. 6545. Sample taken on south wall of slope 20 feet from mouth. Coal dry, but probably weathered.

2. Abandoned prospect, sec. 14, T. 13 S., R. 67 W. Coal bed B.

5. East side of Popes Bluffs, sec. 23, T. 13 S., R. 67 W. Coal bed B.

6. Popes Bluffs, sec. 23, T. 13 S., R. 67 W. Coal bed B.

10. Prospect in sec. 19, T. 13 S., R. 66 W. Coal bed C.

11. Prospect in SE. ¼ NE. ¼ sec. 24, T. 13 S., R. 67 W. Coal bed C; analysis No. 7129. This prospect had not been operated recently and coal is probably weathered.

13. Sec. 24, T. 13 S., R. 67 W. Coal bed C.

18. Neer mine, sec. 13, T. 13 S., R. 67 W. Coal bed A; analysis No. 6439. Sample obtained in main entry 130 feet south of foot of shaft.

21. Carlton mine, sec. 18, T. 13 S., R. 66 W. Coal bed A; analysis No. 6443. Sample taken from face of room 19 off thirteenth entry.

25. Williamsville mine, sec. 29, T. 13 S., R. 66 W. Coal bed A.

26. Danville mine, sec. 29, T. 13 S., R. 66 W. Coal bed A; analysis No. 6442. Sample taken from main slope beyond ninth entry.

27. Curtis mine, sec. 29, T. 13 S., R. 66 W. Coal bed A; analysis No. 6440. Sample taken from back entry off seventh north entry and represents 6 feet 10 inches of the lower bench.

28. Patterson mine, sec. 32, T. 13 S., R. 66 W. Coal bed A.

29. Rapson mine, sec. 33, T. 13 S., R. 66 W. Coal bed A; analysis No. 6441. Sample taken from third room off fourth south entry and represents 5 feet 9 inches of the main bench.

30. Keystone mine, sec. 4, T. 14 S., R. 66 W. Coal bed A; analysis No. 6546. Sample taken in crosscut being driven as an airway to old workings 50 feet south of main entry and 800 feet from foot of shaft.

31. Tudor mine, abandoned slope, sec. 2, T. 14 S., R. 66 W. Coal bed ?.

34. Cell mine, sec. 30, T. 14 S., R. 64 W. Coal bed A; analysis No. 6438. Sample taken at a point 1,050 feet northeast of mouth of slope.

35. Davies mine, sec. 29, T. 14 S., R. 64 W. Coal bed A; analysis No. 6437. Sample taken at a point 425 feet northeast of mouth of main slope.

38. Purdon prospect (not in area represented by the map), SE. ¼ NW. ¼ sec. 27, T. 11 S., R. 61 W. Coal bed ?. Analysis No. 7128.

CHARACTER OF THE COAL.

There is no marked difference in the character of the coal in di parts of this field. In general, it is a lustrous black, rather geneous coal with conchoidal fracture. On close inspectio seen to be less homogeneous than appears at first sight, for it i posed of lenses up to a few feet long, and from a small fractio inch up to several inches thick, of a brilliant glossy black coal, sh in many places the woody structure of the material from wh was derived, in a matrix of a dull black, more granular ma The coal slacks readily on exposure to circulating air, breakin fragments along an irregular network of cracks. Fossil re common in the coal.

The following analyses were made at the Pittsburg laborat the United States Geological Survey on samples collected duri present examination. Each sample was obtained by making across a face of the coal bed, including such parts as were mi could be mined to advantage. The descriptions on page 33 the part of the bed that is represented by the sample. Owing fact that not many mines were in operation, some of the sample taken from old prospect entries, and in such places the co doubtless weathered, although all coal showing effects of weat was carefully removed before sampling was begun. In the mines the coal was fresh, having been taken from a recently w face.

Analyses of coal samples from the Colorado Springs coal field, Colorado.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
					Ft. in.	*Ft. in.*													
6545	SW. ¼	11	13	67	2 7	2 7	11.4	As received	20.2	35.1	37.6	7.09	1.03	5.74	51.64	0.58	33.92	4,857	8,743
								Air dried	9.9	39.6	42.5	8.00	1.16	5.04	58.29	.65	26.86	5,482	9,868
								Dry coal		44.0	47.1	8.88	1.29	4.38	64.66	.73	20.06	6,082	10,948
								Pure coal[a]		48.3	51.7		1.42	4.81	70.96	.80	22.01	6,675	12,015
6439		13	13	67	4 7	4 7	17.4	As received	22.2	34.6	37.4	5.8	.47					4,724	8,503
								Air dried	5.8	41.9	45.2	7.1	.57					5,719	10,294
								Dry coal		44.4	48.1	7.5	.60					6,071	10,928
								Pure coal		48.0	52.0		.65					6,563	11,813
6443		18	13	66	8 7	6 10	15.3	As received	25.5	31.6	38.1	4.8	.25					4,614	8,305
								Air dried	12.1	37.3	44.9	5.7	.30					5,448	9,806
								Dry coal		42.4	51.1	6.5	.34					6,195	11,151
								Pure coal		45.3	54.7		.36					6,626	11,927
6442		29	13	66	8 10	6 5	15.4	As received	21.8	33.6	37.9	6.7	.40					4,735	8,523
								Air dried	7.6	39.7	44.8	7.9	.47					5,597	10,075
								Dry coal		43.0	48.5	8.5	.51					6,055	10,899
								Pure coal		47.0	53.0		.56					6,620	11,916
6440		29	13	66	12 9	6 10	15.6	As received	20.9	33.7	39.9	5.53	.39	6.05	52.25	.69	35.09	4,951	8,912
								Air dried	6.3	39.9	47.2	6.55	.46	5.12	61.91	.82	25.14	5,866	10,559
								Dry coal		42.6	50.4	6.99	.49	4.72	66.07	.87	20.86	6,261	11,270
								Pure coal		45.8	54.2		.53	5.07	71.04	.94	22.42	6,732	12,118
6441		33	13	66	8	5 9	14.6	As received	19.9	34.3	38.3	7.5	.37					4,802	8,643
								Air dried	6.2	40.1	44.9	8.8	.43					5,623	10,121
								Dry coal		42.8	47.9	9.3	.46					5,995	10,791
								Pure coal		47.2	52.8		.51					6,613	11,903
6546	NE. ¼	4	14	66	5 7	5 7	16.9	As received	25.6	30.2	38.6	5.57	.42	6.32	51.69	.71	35.29	4,848	8,726
								Air dried	10.5	36.3	46.5	6.70	.50	5.34	62.21	.85	24.40	5,834	10,501
								Dry coal		40.6	51.9	7.49	.56	4.67	69.51	.95	16.82	6,520	11,736
								Pure coal		43.9	56.1		.61	5.05	75.14	1.03	18.17	7,048	12,686

Analyses of coal samples from the Colorado Springs coal field, Colorado—Continued.

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
					Ft. in.	*Ft. in.*													
6438	....	30	14	64	4 7	3 6	14.5	As received.....	19.2	32.4	41.4	7.02	0.45	5.79	53.63	0.86	32.25	5,170	9,306
								Air dried.......	5.5	37.8	48.5	8.21	.53	4.89	62.73	1.01	22.63	6,047	10,885
								Dry coal.......	....	40.0	51.3	8.69	.56	4.52	66.40	1.06	18.77	6,401	11,522
								Pure coal.......	....	43.8	56.2	....	.61	4.95	72.72	1.16	20.56	7,010	12,628
6437	....	29	14	64	4 8	3 5	18.0	As received.....	22.1	32.5	38.9	6.5	.48	....	....	....	....	5,631	10,136
								Air dried.......	5.0	39.6	47.4	8.0	.58	....	....	....	....	6,121	11,018
								Dry coal.......	....	41.7	49.9	8.4	.62	....	....	....	....	7,230	13,014
								Pure coal.......	....	45.5	54.5	....	.68	....	....	....	....	7,893	14,207
7129	SE. ¼	24	13	67	2 4	2 4	14.5	As received.....	23.1	31.2	35.6	10.13	.21	5.77	47.69	.64	35.56	4,461	8,030
	NE. ¼							Air dried.......	10.0	36.5	41.6	11.85	.25	4.86	55.78	.75	26.51	5,218	9,392
								Dry coal.......	....	40.5	46.3	13.17	.27	4.17	61.99	.83	19.57	5,799	10,438
								Pure coal.......	....	46.7	53.3	....	.31	4.80	71.39	.96	22.54	6,779	12,022
7128	SE. ¼	27	11	61	1 9½	1 9½	26.4	As received.....	34.4	24.4	27.3	13.89	.14	6.46	35.94	.66	42.91	3,364	6,055
	NW. ¼							Air dried.......	10.9	33.2	37.0	18.87	.19	4.80	48.83	.89	26.42	4,571	8,228
								Dry coal.......	....	37.2	41.6	21.17	.21	4.02	54.79	1.01	18.80	5,128	9,230
								Pure coal.......	....	47.3	52.7	....	.27	5.10	69.51	1.28	23.84	6,505	11,709

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated, but owing to the briefness and convenience of the term, it is used in this report as noted above.

DEVELOPMENT AND MARKETS.

A brief review of the history of mining in the region, gathered from reports such as those of the state coal-mine inspector of Colorado and from the Mineral Resources volumes published by the United States Geological Survey, is given below.

In the first volume of Mineral Resources[a] occurs this statement concerning El Paso County:

> The only mines worked to any extent are those owned by the Denver and New Orleans Railroad Company at Franceville * * *. The product has only become available since the completion of the Denver and New Orleans Railroad in July, 1882.

That coal was taken out for local use before that time is quite possible, but it is impossible to trace the history of such small-scale working of coal seams by any authentic records; very likely such operations began with the earliest settlement of the region.

The Franceville mine was operated from the middle of 1882, apparently, till 1898, which is the last year for which its production is reported by the state inspector of coal mines. During that period it produced the following annual amounts:

Production of Franceville coal mine, 1882-1898.

	Short tons.		Short tons.
1882	23,689	1891	1,064
1883	54,416	1892	26,000
1884	56,070	1893	10,000
1885	39,038	1894	No report.
1886	50,000	1895	7,943
1887	47,017	1896	16,413
1888	39,144	1897	15,517
1889	27,926	1898	10,409
1890	9,335		

The McFerran mine commenced producing in November, 1888.[b] In 1896 it was abandoned and the inspector says:[c] "It appears that the mine has never been on a paying basis." A table of its production follows:

Production of McFerran coal mine, 1888-1896.

	Short tons.		Short tons.
1888	5,000	1893	19,318
1889	26,140	1894	No report.
1890	17,512	1895	41,995
1891	33,300	1896	8,424
1892	9,788		

Until 1896 the McFerran and Franceville mines were the only ones reported for El Paso County by the state inspector. About that year, apparently, several small mines were opened in the west end of the field—that is, north of Colorado Springs—only to be abandoned within the next year or two. Of the present larger mines north of the town the Carlton or Pikeview was the first to be opened. Shaft sinking was begun in the latter part of 1896 and the main coal was struck January 1, 1897.[a]

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[a] Mineral Resources U. S. for 1882, U. S. Geol. Survey, 1883, p. 39.

[b] Third Bienn. Rept. Colorado State Coal-Mine Insp., p. 104.

[c] Seventh Bienn. Rept. Colorado State Coal-Mine Insp., p. 36.

The Curtis, Danville, and Williamsville mines followed within the next year, and others, some of them now abandoned, were opened from time to time thereafter.

The principal developments at present are the group of mines about 2 miles north of Colorado Springs. Of these only the Curtis and Rapson have shafts, the others being slope mines. The room and pillar method of extracting the coal is used entirely, with pillars about 18 feet thick and rooms about 22 feet wide. Some coal is almost always left in the roof because the rock overlying the coal is in most places a very weak sandy clay. As the coal in these mines is of good quality and abundant to meet present demands, there has been no effort to develop the deeper-lying portions of the bed. The depth of the Carlton or Pikeview shaft, the deepest in the field, is 175 feet.

The Neer mine is also opened by a shaft and is working on about 3 feet of coal believed to be coal A.

On coal B the only mine now operating is the Monument Valley, in the SW. ¼ sec. 11, T. 13 S., R. 67 W., near the south line of the section. This mine differs from all the others in that the bed dips steeply, and hence the slope starts directly on the coal. It was reopened so near the end of the field season that there was no time to examine the deeper workings. At the mouth of the slope the coal is about 3 feet thick; in depth, 4 feet of it is reported.

The only mines operating farther east are the Cell, or new Franceville, and the Davies mine, in the southwestern part of T. 14 S., R. 64 W. Both of these are slope mines with about 3½ to 4 feet of coal.

The coal of the Colorado Springs field is used largely for domestic purposes. It seems in addition to be very satisfactory for burning under boilers, as it is applied in this way by such plants as those of the Colorado Springs Electric Company and the mills in Colorado City and at Cripple Creek. The mines at Franceville supply a wagon trade entirely, for use mainly by creameries and ranches.

Any part of the field can be easily entered by a railroad; in fact, there were branches to the old Franceville and McFerran mines while they were still operating.

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[a] Eighth Bienn. Rept. Colorado State Coal-Mine Insp., p. 74.

THE CANON CITY COAL FIELD, COLORADO.

By Chester W. Washburne.

INTRODUCTION.

The Canon City coal field is located on the east front of the Rocky Mountains in south-central Colorado. It is one of the earliest developed coal fields of the State and is one of the best known, producing a high-grade, clean, dry domestic fuel.

The following paper sums up briefly the principal results of a reconnaissance examination made in the summer of 1908. Many of the east-west section lines were traversed on foot, distance being determined by pacing and points located by compass intersections. The outcrops of the coal beds were meandered in the same way, and sections of the beds were made in the mines and prospects, it being impossible to measure the coal elsewhere. The original purpose of the work was land classification, and when it was ascertained that no coal land remained in possession of the Government no attempt was made to dig into the weathered outcrops to measure the coal beds, and only such data were gathered as seemed most useful to those engaged in prospecting or developing the field. No attempt was made to sketch the topography. The more detailed results of this work will be presented in a later publication.

TOPOGRAPHY.

The Canon City coal field occupies a small mesa at the foot of Wet Mountain and west of a broad valley of Pierre shale, in which lies the Florence oil field. The mesa rises gradually westward in smooth grassy plains that merge with Wet Mountain in the southern part of the coal field. In the northern part of the field there is a depression in the mesa, known as Wolf Park, west of which is a sharp ridge of the upturned sandstone of the Laramie formation separating this park from the shale valley that lies at the foot of Wet Mountain. The north and east sides of the coal field are marked by a series of high cliffs characterized by projecting points and deep reentrants. The latter were cut by small creeks, most of which are intermittent in flow, but Newland, Oak, and Chandler creeks, which rise in Wet Mountain, carry a perennial flow across the coal field.

Small pine and oak trees grow over most of the northern part of the mesa and along the stream courses in the southern part. These are not suitable for mine timber, and consequently material for this purpose must either be hauled by wagon from Wet Mountain or shipped by rail from distant places. There is a good growth of grass on the mesa which is green for the greater part of the year. The principal wagon roads across the field follow the sharp canyons. Elsewhere travel is difficult, owing to the abundance of small gullies and cliffs.

Spurs from the Denver and Rio Grande and the Atchison, Topeka and Santa Fe railroads reach all the principal mines in the northern and eastern parts of the field. The southwestern part has no railroad connection and therefore no important mines.

GENERAL GEOLOGY.

STRUCTURE.

Throughout the greater part of the coal field the strata dip gently westward at angles varying from 2° to 5°. Along the western margin the strata are sharply upturned, probably from the influence of a thrust fault at the foot of Wet Mountain. This fault cuts across the coal measures in the southern part of the field and is marked by a complete overturn of the beds in that locality. (See Pl. XVIII.) The coal beds are there overlain by granite which has been thrust upon them. On tracing the coal beds northward from the granite contact they are seen to be overturned, having westward dips of about 45° for a distance of over a mile; farther north they are upright for several miles and acquire progressively lower eastward dips as they leave the influence of the Wet Mountain fault. At the northwest end of the field, where, owing to its distance, the influence of the fault is slight, the dips are only 12° to 20°. The structural features are best shown by the dip symbols on the accompanying map (Pl. XVIII).

STRATIGRAPHY.

The coal beds of the Canon City field occur in the Laramie formation. Beneath the Laramie is the Trinidad sandstone, which rests on Pierre shale. Various Mesozoic and Paleozoic strata lie between the Pierre shale and the Archean granite, but these have no economic bearing on the coal field and therefore will not be described in this paper. Above the Laramie is conglomerate, probably equivalent to the Arapahoe conglomerate of the Denver Basin and the Poison Canyon formation of the Trinidad field. A small remnant of tuffaceous sandstone and shale, probably corresponding with a part of the Denver formation, rests at one locality on the Arapahoe (?) conglomerate.

PIERRE SHALE.

The Pierre shale is a remarkably uniform body of consolidated sea mud, soft dark gray to greenish black at the surface of the ground. The fresh unweathered shale is firm and readily fissile along the bedding planes, as shown by the flat platy character of the drillings from oil wells. Considerable bodies of it are almost white, although dark-gray to bluish-black colors prevail. It contains numerous large, hard calcareous concretions, a few of which make "tepee buttes" on the low plains north and east of the coal field. Small hard, brittle ferrocalcareous concretions are abundant at certain horizons. In grading a street in the western part of Florence a bed of bluish-white limestone, about 2 inches thick, was observed, but this is the only occurrence of limestone in the upper part of the Pierre shale observed in this region. Near the base of the shale are a few nonpersistent beds of very impure limestone 1 to 8 inches thick. Beds of sandstone 6 inches to 3 feet thick are common in the upper 300 feet, and in this zone there are in most sections one or two beds of resistant sandstone 5 to 10 feet thick. A few thin beds of sandstone are found as far as 700 feet below the top of the Pierre, but there are none below that horizon. As the base of the overlying Trinidad sandstone is approached, sand and clay become equally important constituents of the section and are distributed in a peculiar and interesting way. Beds of sandstone 4 to 8 inches thick alternate with beds of shale 2 to 6 inches thick, through a distance of 30 to 50 feet below the base of the Trinidad sandstone. This regular alternation of coarse and fine sediment is suggestive of the work of periodic floods alternating with slower currents at the mouth of a river. At one locality fifty-two of these beds of sandstone separated by partings of shale were counted in a section 45 feet thick. The beds contain no fossils on the east side of the field, but on the west side the leaves of deciduous plants are abundant in both the sandstone and the shale. At different horizons in the underlying shale are found many marine Upper Cretaceous bivalves and ammonites.

TRINIDAD SANDSTONE.

The Trinidad sandstone is a massive, yellow-weathering sandstone, thin bedded near the base, where it grades imperceptibly into the Pierre shale. Layers of clay become increasingly abundant toward the bottom of the sandstone, and in the upper part of the shale layers of sandstone become increasingly abundant toward the top. The boundary between the two is uncertain, and the base of the former in the Canon City field may not correspond exactly with the base of the Trinidad sandstone in the Trinidad field. In the latter locality the top of the Pierre shale contains invertebrate fossils of the same types as those found at the same horizon near Canon City. Moreover, the name Trinidad sandstone is now well established in this field, because both geologists and miners have observed the lithologic similarity between the sandstone at the base of the coal-bearing strata at Trinidad and the sandstone at the base of the coal-bearing strata of the Canon City field. The continued use of the name Trinidad sandstone therefore seems preferable to the introduction of a new name, although it must be admitted that the sandstones may not be precisely synchronous deposits.

As recognized in this field the Trinidad sandstone ranges from 50 to 100 feet in thickness and includes only the massive sandstone beneath the Rockvale coal bed. For about 50 feet below it sandstone and shale are present in nearly equal amounts, and, as already mentioned, the upper 300 feet of the Pierre shale is very sandy. As the base of the Trinidad sandstone is not a sharp line, other observers might prefer to place it as much as 300 feet or more below the Rockvale coal, thus including sandstones and sandy shales which the writer has considered merely sandy members of the Pierre shale.

No fossils were found in the Trinidad sandstone, not even the peculiar lozenge-pattern prints of the marine plant often called fossil corncobs (*Halymenites major*), which is elsewhere so characteristic of this sandstone. The search for fossils in the Trinidad was not thorough, yet was sufficient to show that *Halymenites* is either absent or at least rare in the Trinidad at Canon City, although in a yellow sandstone in the coal measures about 300 feet above the Trinidad this fossil is very abundant. The sandstone is more massive and, in places, strongly cross-bedded on the west side of the coal field, suggesting that Wet Mountain was land and that the Canon City embayment was occupied by the sea at the time the Trinidad sandstone was deposited.

LARAMIE FORMATION.

The Laramie formation, which contains all the coal beds of the Canon City field, rests conformably on the Trinidad sandstone and is unconformably overlain by the Arapahoe (?) conglomerate. The productive division of the formation is the lower 600 to 700 feet, consisting of sandstone and dark-colored, usually carbonaceous shale. On the east side of the field the lower third of the productive division consists mainly of sandstone and the upper two-thirds mainly of shale, but on the west side sandstone predominates over shale in all parts of this division. Overlying the productive division is a resistant, massive sandstone about 250 feet thick, which is a controlling factor in the topography, producing a sharp ridge where it stands vertical along the western margin of the field and causing the high escarpment of nearly horizontal coal-bearing strata which it caps on he east side of the field. Above the resistant sandstone at Alkali ap there is 255 feet of soft yellow sandstone in beds 2 to 5 feet thick parated by sandy shale and probably by some dark carbonaceous ale, but over the greater part of the field this, the highest member f the Laramie formation, is absent and the Arapahoe (?) conglomrate rests directly on the underlying thick massive sandstone. The haracter of the formation in the western part of the field is shown y the following detailed section of the rocks, which was measured y C. A. Fisher and the writer with a steel tape.

Section of rocks in Alkali Gap.

	Ft.	In.
Sandstone, tuffaceous, and bright colored clay, probably Denver formation, nearly horizontal	50	
Not exposed, horizontal distance 325 feet, dip unknown	?	
Sandstone, mostly, with layers of conglomerate, dip 75° E	160	
Not exposed, soft, probably dark shale	60	
Conglomerate	260	
Total exposed Arapahoe (?)[a]	480+	
Unconformity.		
Sandstone, soft, with streaks of sandy shale, nearly vertical	255	
Sandstone, strong, massive, makes crest of ridge	250	
Not exposed, probably mostly soft sandstone, some fire clay at top	40	
Coal, thin bed.		
Sandstone	25	
Not exposed, soft rocks	20	
Coal, probably Brookside bed	3	
Shale	2	
Sandstone, white, even bedded	20	
Sandstone, soft	35	
Not exposed	30	
Coal, in black shale	1	6
Not exposed	20	
Sandstone, with fossil leaves at base	55	
Coal, Chandler bed, in an open cut	4–5	
Sandstone and shale	40	
Coal, top not exposed	1+	
Sandstone, coarse grained, massive, with iron concretions, weathers yellow	65	
Sandstone, shaly	30	
Coal, upper Royal Gorge bed	4	
Shale, hard, sandy	10	
Coal, bloom, lower Royal Gorge bed[b]	4	
Sandstone, soft, white	27	
Shale, with coaly streaks	5	

In the Littell shaft, 1 mile east of Alkali Gap, the thickness of the Arapahoe (?) is about 550 feet.

Measurement obtained in the Royal Gorge mine. The lower bed can not be measured in Alkali Gap thout considerable digging.

	Ft.	in.
Sandstone, soft, gray	31	
Coal Coal, 2 feet Shale, 1 foo Coal, 1 foot	4	
Not well exposed, probably mostly shale	41	
Sandstone, hard	8	
Not well exposed, mostly shale	52	
Coal	2	6
Sandstone and shale, with a nonworkable bed of coal near base.	63	
Coal	?	
Sandstone	15	
Coal	?	
Shale	25	
Coal Coal, 1 foot Shale, 1 foot Coal, 1 foot 8 inches Nonac bed	3	8
Sandstone, coarse, white	50	
Coal, Rockvale bed		2–6
Total Laramie	1,242	
Sandstone, Trinidad	55	
Shale, blue, sandy	45	
Sandstone	1	
Shale	5	
Sandstone, massive	8	
Shale, blue, sandy, with thin partings of sandstone	40	
Shale, sandy, yellow, containing large concretions with Pierre fossils	45	
Shale, blue, sandy, with concretions	65	
Sandstone, soft, shaly	4	
Shale, sandy, blue, yellow, white	50	
Shale, blue, containing at base concretions with *Lucina occidentalis*	250	
Shale, blue-black, with thin indurated sandy layers containing comminuted plant fragments	150	
Shale, clayey, dark, slickensided[a]	3,000	
Total Pierre and Trinidad	3,718	
Fault.		
Granite.		

Coal is present only in the lower 600 feet of the Laramie formation, the overlying sandstones being barren in this field.

The rocks of the Laramie formation become much finer in grain toward the east side of the coal field. This change is especially noticeable in the upper part of the productive division, which consists principally of shale in the eastern part of the field and largely of sandstone in the western part, although there is considerable shale at the west also, as shown by the section in Alkali Gap given above. For comparison with the Alkali Gap section, the following measurements of the strata exposed in the bluff north of Rockvale may be of interest.

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[a] The entire thickness of the Pierre shale is not present at this locality. In the Florence oil field it measures about 4,500 feet. See p. 519.

Section of part of the Laramie formation on the hillside north of Rockvale.

	Ft.	in.
Sandstone, massive, probably part of the big barren sandstone..	25	
Not exposed	15	
Coal, blossom	?	
Shale	25	
Sandstone	10	
Shale	25	
Coal, surface measurement	2	
Shale, dark, with three 1-foot beds of sandstone	25	
Coal, surface measurement		6
Shale, dark	35	
Sandstone, soft, and sandy shale	5	
Sandstone, strong, thin bedded, fine grained	6	
Coal, blossom, thickness probably	1	
Shale, mostly dark colored, with streaks of coal	45	
Sandstone, shaly	8	
Shale	4	
Sandstone	5	
Shale, carbonaceous	15	
Sandstone, soft, with layers of firm white shale	5	
Shale, dark, carbonaceous	12	
Sandstone, resistant	10	
Shale, dark	13	
Coal		2
Clay		2
Coal, surface measurement	1	
Bone	1	
Sandstone, soft, coarse grained, white, with brown ironstone concretions	8	
Shale	5	
Sandstone		6
Shale, black, carbonaceous, with many black clay-ironstone concretions	25	
Sandstone and shale, soft	4	
Coal, surface measurement	1	
Shale, sandy, weathering white	20	
Shale, black, carbonaceous	25	
Sandstone, massive	10	
Shale, carbonaceous	15	
Sandstone, strong, with gnarly brown concretions at top	12	
Shale, sandy	5	
Sandstones, massive	8	
Coal, surface measurement	2	2
Shale, carbonaceous and sandy	10	
Not exposed, rock beneath the valley	350±	
	794	6

The lower two-thirds of the concealed strata at the base of this section was measured near the Bluff Springs mine and a section of the rocks will be found on page 355. F.H.Knowlton reports that the upper part of the coal measures contains a flora equivalent to that of the Laramie formation of the Denver Basin, but that the lower part contains a flora of upper Montana age. According to the original definition of the Laramie by which the term includes the coal-bearing strata resting conformably on the top of the marine Cretaceous, there seems to be no good reason for separating these lower beds from the Laramie even though they contain an upper Montana flora. There is no noticeable lithologic change within the coal-bearing strata that can furnish a satisfactory basis of subdivision into a Laramie and an upper Montana formation, except on the eastern edge of the field north of Radiant, where a yellow thin-bedded sandstone 40 to 70 feet thick contains many impressions of *Halymenites major*, a marine plant. Knowlton reports that this sandstone separates the strata containing an upper Montana flora from the overlying beds, which contain a flora similar to the Laramie. When the sandstone is traced toward the mountains either southward beyond Radiant or westward to the west side of the field, it is seen to lose its marine character, its thin bedding, fossils, etc., and to become massive, coarse grained, and cross-bedded, acquiring all the characters of a fluviatile sandstone. On the west side of the field it is impossible to distinguish this sandstone from others above and below it, except by careful comparison of detailed sections, and it therefore has little value as a horizon marker in that region.

The lithologic succession in this field is almost precisely identical with that at Denver, and the writer therefore does not hesitate to correlate the strata of the Canon City coal field with those of the Denver Basin, admitting that on paleobotanic evidence the lower coal beds may be somewhat older than the lowest coal at Denver.

ARAPAHOE (?) CONGLOMERATE.

The Arapahoe (?) conglomerate rests unconformably on the sandstone at the top of the Laramie formation. In the Alkali Gap section (see p. 345), the conglomerate rests on a soft, distinctly bedded sandstone with layers of sandy shale, which measures 255 feet in thickness. This sandstone thins out northward, on account of pre-Arapahoe erosion, and half a mile north of Alkali Gap, opposite the Royal Gorge coal mine, the conglomerate lies directly on the lower resistant massive sandstone, which there measures about 235 feet in thickness. Apparently erosion had cut about 270 feet deeper in the rocks at the latter locality than it had at Alkali Gap before the deposition of the conglomerate. Over the whole of the Canon City field, except at

Alkali Gap, the conglomerate rests on the resistant massive sandstone, and the overlying soft sandstone is absent. At the gap the soft sandstone was presumably in some way protected from erosion.

As the Arapahoe (?) conglomerate lies unconformably on the Laramie it is not surprising that a few fragments of sandstone and coal of the Laramie are present in the conglomerate. Fragments of Pierre shale were not seen in the conglomerate, but the Niobrara and Paleozoic limestones and cherts and the Dakota (?) sandstone are represented by a few pebbles, and one fragment of Ordovician sandstone containing a fish scale was found. Small waterworn pieces of red sandstone from the "Red Beds" and rounded quartzite pebbles from an unknown source are abundant. Pebbles of all these rocks, however, are greatly outnumbered by those of Archean granite, granite gneiss, schist, quartz, and coarse-grained igneous rocks that intruded the Archean complex in pre-Ordovician time. The last-named rocks are common in Wet Mountain and all the sedimentary rocks which compose the minor part of the Arapahoe (?) conglomerate are found upturned along the front of the mountain, except that there is no quartzite like that of the pebbles. Diligent search failed to reveal any pebbles of effusive igneous lava or tuff such as characterize the Denver formation, but pebbles of coarse-grained porphyries are numerous, being probably derived from pre-Ordovician intrusions in the Archean complex. Granite pebbles and small pieces of granitic quartz and feldspar are by far the most abundant constituents of the conglomerate. Although the pebbles of sedimentary rock seem to be most plentiful in certain layers near the middle of the formation, there is essentially no difference in the materials of the conglomerate from bottom to top.

In Alkali Gap the lower 260 feet of the Arapahoe (?) is pure conglomerate with very little sand. It outcrops in massive beds about 20 feet thick. The basal bed contains the largest pebbles, which range from 3 to 10 inches in diameter and are mostly subangular but slightly waterworn. The rare quartzite pebbles, however, are all well rounded and smooth. Above the massive conglomerate are 60 feet of poorly exposed strata, probably soft sandstone or sandy shale, and some dark carbonaceous shale, seen only in the débris of rodent holes. In the succeeding 160 feet of strata there are four beds of pebbly sandstone, each about 10 feet thick, separated by intervals of 30 to 40 feet in which the rock is not exposed. To judge from the soil, the débris of prairie-dog holes, etc., these intervals in which the rock is not exposed are occupied by coarse sandstone, possibly with pebbly layers. The pebbles in the sandstone beds are mostly in layers 6 to 18 inches thick. They are similar in material to those in the underlying conglomerate, but are smaller, one-fourth inch to 1 inch in diameter, and more nearly rounded. Quartz pebbles are more abundant in the upper layers than in the massive conglomerate. These are the highest beds of the Arapahoe (?) conglomerate observed in the Canon City field. They dip 75° to 85° E. The succeeding interval, across 325 feet of ground, contains no exposures. The next exposure is that of beds of the Denver (?) formation lying horizontally. If the concealed rocks stand nearly vertical in this interval, they are about 325 feet thick, but it is probable that the dip is less steep and consequently that the thickness is much less than 325 feet, perhaps about 70 to 100 feet, for the total thickness of the Arapahoe (?) in the Littell shaft, about one-fourth mile east of this locality, is only 550 feet, the lower 480 feet of which has already been described as occurring at Alkali Gap, leaving only 70 feet to be accounted for. It is in this interval that the beds change abruptly from a nearly horizontal to a nearly vertical position.

The Arapahoe (?) conglomerate underlies the whole of Wolf Park, extending at least as far south as Chandler. Along the wagon road between Canon City and Chandler the conglomerate is well exposed on some high hills, where it dips northwestward at a low angle. In the southern part of the field it lies along the axis of the syncline, which is west of the center of the field. Its eastern margin can not be observed in the southern area, and its position as shown on the accompanying map (Pl. XVIII) is largely conjectural.

The Arapahoe (?) is very different from the underlying formations in the character and coarseness of its material. The presence of material from these formations in its pebbles indicates that a long period of erosion preceded the deposition of the conglomerate. The fact that it was involved in the last great orographic movements of the Rocky Mountains prevents the possibility of confusing it with late Tertiary gravel. The writer follows Eldridge, Hills, and others in correlating this formation with the Arapahoe of the Denver Basin.

DENVER (?) FORMATION.

At a distance of 325 feet east of the last exposure of Arapahoe (?) conglomerate in Alkali Gap the small creek that flows through the gap has undercut a few feet of green and red clays containing thin beds of brown and yellow sandstone with pebbly layers. The beds lie nearly flat, dipping not more than 3° or 4° E., but this does not indicate that they have not been involved in the folding of the lower formations. The structure makes it highly probable that the lower formations are also nearly horizontal at this locality. The exposure is imperfect. There is no indication of the existence of more than 50 feet of rocks assignable to this formation, yet from the presence of tuffaceous and andesitic material in the pebbles first reported by Eldridge, it seems best to follow him in considering the exposure a probable small remnant of the Denver formation. The rocks should be separated from the Arapahoe (?) conglomerate because of the presence of the distinctive andesite and red and green clays. There is no evidence of the existence of more than 1 acre of Denver (?) rocks, but more may be concealed beneath the valley wash on the west side of Wolf Park, outside of which it is not possible for any Denver (?) strata to be left in this region.

THE COAL.

STRATIGRAPHIC POSITION OF COAL BEDS.

As mentioned above, all the workable coal beds are in the Laramie formation. Indications of coal have been found in the Dakota sandstone, but as a rule the beds are thin and apparently of no value. (See p. 371.)

The correlation of coal beds which can not be accurately traced on the surface is not an easy matter; nevertheless the approximate position of any bed may be determined by geologic methods without serious error. In the following table the endeavor is made to project all the known coal beds on a section of the Laramie formation measured near Rockvale, for the purpose of showing the relative position of the beds. Some generalization has been necessary on account of differences in thickness of the beds away from the Rockvale section, and because not all of the coal beds are present in that section. The coal of many of the horizons can not be traced from one mine to another, and it is known that some of the coals are not continuous between mines that work beds at probably the same horizon.

Section of the Laramie formation in Canon City coal field, Colorado, showing the relative positions of the coal beds.

Unconformity at the base of the Arapahoe (?) conglomerate.	Feet.
Sandstone, resistant	250–500
Sandstone, soft, and shale, with thin coal beds	125
Horizon of the coal bed of the Brookside and Brilliant mines.	
Interval, mostly sandstone, with thin coals	75–165
Horizon of the coal bed of the Chandler and Littell mines and of the Simons prospect in Alkali Gap.	
Interval, mostly sandstone	95–135
Horizon of the Royal Gorge coal beds and possibly of the Bassick bed.	
Interval, mostly sandstone	70
Horizon of the Radiant coal bed.	
Interval, mostly shale	75–100
Horizon of the coal of the Ocean Wave or Magnet mine.	
Interval, sandstone and shale, with thin beds of coal	100–115
Horizon of the coal of the Nonac and Diamond mines.	
Sandstone	30– 50
Horizon of the coal of the Fremont, Rockvale, Coal Creek, and Bluff Springs mines. This coal bed is considered the base of the Laramie formation.	
Trinidad sandstone.	

DESCRIPTION OF MINES AND PROSPECTS.

Rockvale mine.—The Rockvale mine is the largest in the Canon City field, producing an average of 850 to 900 tons a day and at times over 1,000 tons a day. The mine is about thirty-five years old, having been first opened by the Santa Fe Railway Company from a shaft (Santa Fe No. 4), located one-half mile northeast of the present Rockvale shaft, which was completed by the Colorado Coal and Iron Company in 1881. The mine is operated by the latter company, reorganized under the name Colorado Fuel and Iron Company.

The Rockvale mine is in the lowest bed in the field and its workings merge and intercommunicate with those of the Fremont and Coal Creek mines, both of which are also operated and owned by the Colorado Fuel and Iron Company. The coal is hoisted by steam power through a two-compartment shaft 323 feet deep, the top of which coincides with the upper surface of the yellow sandstone, which here contains abundant impressions of *Halymenites*. The coal is dumped from a wooden tipple over screens directly into coal cars, most of the lump coal being loaded into box cars by a steel box-car loader operated by electricity. The fine coal is washed but does not find a ready market, and in 1908 a large amount of slack was piled beside the railroad track.

The coal bed rests on the Trinidad sandstone at the base of the Laramie formation. In the Rockvale mine it slopes westward from 6 to 6½ per cent and varies in thickness from 3 feet 4 inches to 4 feet, the thicker coal invariably being overlain by "draw slate" and the thinner coal usually by sandstone. This relation prevails throughout the three adjacent mines, Fremont, Rockvale, and Coal Creek, and is probably due to the erosion of the original clay and of the top of the original peat, which were consolidated to the "draw slate" and the coal, respectively. The erosion is supposed to have been effected by the swifter current that deposited the sand of the overlying sandstone. By platting the position of the places where the sandstone roof comes in contact with the coal in the three mines, significant relations have been discovered between the character of the coal beds, especially in regard to roof and partings, and the position of the stream channels in the swamps of the coal-forming period. The main stream channel as thus located lies just north of the Fremont workings, in the northern part of which the coal is of little value on account of partings. These relations will be fully discussed in the final report.

Mining is done wholly by hand in the Rockvale mine, the long-wall method being followed. The distribution of joints in the coal makes driving easiest in a northeast or southwest direction. In the first entry north of the C dip slope off the main south slope the butts trend N. 40° E. and the faces N. 50° W. The butts are 2 to 8 inches apart, with an average of about 5 inches; the faces are strongly developed and the distance between them varies from 1 to 4 inches, averaging about 3 inches. The joints appear to be of the same general character wherever examined in this mine. In the fourth entry south of the C dip slope off the main south slope the butts trend N. 45° E. and are spaced 2 to 12 inches, with an average of about 6 inches; the faces trend N. 50° W. and are spaced 1 to 3 inches, with an average of about 1½ inches.

The coal breaks down in lumps 1 to 3 feet across, with considerable quantities of finer débris. It is reported that in this mine, as well as in most of the other mines, the introduction of foreign workmen as a result of labor troubles in recent years has caused a marked falling off in the percentage of lump coal produced and in the general efficiency of the working force. As the Canon City coal is mined principally for domestic use, for which it commands a high price, the percentage of lump coal is an important factor in mine management.

In the Rockvale mine the coal cars are hauled by mules to the main slope, where they are attched to a cable and drawn by electric drums to the foot of the shaft. Gas is not abundant and the small amount present appears to come mainly from the coal and only in part from the roof.

Fremont mine.—The Fremont mine is on the same coal bed as the Rockvale mine and the workings of the two intercommunicate underground. The shaft of the Fremont is located about 1½ miles northwest of the Rockvale. The Fremont mine is operated by the Colorado Fuel and Iron Company and produces about 400 tons of coal a day in the following proportions: Lump coal, passing over 3-inch perforated shaker screen, 50–51 per cent; nut coal, 22–23 per cent; slack and pea coal, 21–22 per cent.

The shaft is 402 feet deep and is equipped with a hoist of 100 horsepower, steel top frame, and self-dumping cages handling about 75 cars an hour. The tipple is also built of steel and has a steam box-car loader and shaker screens. The trips of coal cars are hauled to the foot of the shaft by a 75-horsepower electric traction motor. Water is pumped by two small electric pumps from the working faces to a sump at the foot of the main shaft, whence it is raised to the surface by a 75-horsepower electric pump working two hours a day at a rate of 50 gallons a minute. In 1908 about 180 men were employed underground and 35 at the surface. The miners receive 85 cents a ton for hand mining.

The coal bed has an average thickness of about 4 feet, ranging from 3 feet to 3 feet 6 inches under the sandstone cap rock and from 4 feet 6 inches to 5 feet under shale. Sandstone comes into contact with the coal in the southeastern part of the mine, but in most other parts the cap rock is shale. The line of separation between the areas of sandstone and of shale cap rocks trends in a general northeast-southwest direction, running about 1,000 feet south of the shaft and continuing into the Rockvale mine. Southeast of this line the cap rock is sandstone in most places. Northwest of the line the cap rock is sandstone only where rolls or similar irregularities permit it to descend through the shale, which varies from 1 to 7 feet in thickness.

Joints are well developed in this mine. The butts trend N. 40° E. and are about three-fourths of an inch apart; the faces trend N. 50° W. and are half an inch to 2½ inches apart.

Coal Creek mine.—The Coal Creek mine of the Colorado Fuel and Iron Company is located in sec. 31, T. 19 S., R. 69 W., and ships its product over a spur of the Denver and Rio Grande Railroad running 3 miles northeastward to Florence. The mine is worked by a slope which now extends about a mile west of the entrance and has a dip of about 3°. It was first operated from a slope that lies three-fourths of a mile north of the present location and is commonly known as the old Coal Creek slope or the Canfield mine. The Coal Creek mine was not entered by the writer because of its proximity to the Rockvale and Bluff Springs mines, which work the same coal bed at the base of the Laramie formation.

The mine maps kindly furnished by the Colorado Fuel and Iron Company show that the thickness of the coal bed near the center of the SW. ¼ sec. 31, T. 19 S., R. 69 W., is 3 feet 3 inches, and one-fourth mile north of the southwest corner of sec. 31, T. 19 S., R. 69 W., 3 feet 6 inches.

Seven feet above the Rockvale bed at Coal Creek there is about a foot of coal which persistently accompanies the Rockvale bed in this part of the field. Its distance from the Rockvale bed increases toward the north to 10 feet in the Rockvale mine and to 15 feet in the Fremont mine. In the southwestern part of the Coal Creek mine the intervening rock, principally sandstone, which separates the top coal from the main bed, wedges out and permits the top coal to rest on the main bed with only a trace of separating clay.

The mining operations at Coal Creek are similar to those at Rockvale, the long-wall method being used exclusively. The production is somewhat smaller than that at Rockvale, owing largely to the fact that a slope is slower to operate than a shaft. Mining at Coal Creek is facilitated by the ease with which the coal breaks from the roof, owing to an intervening thin parting of argillaceous rock. In most parts of the Rockvale mine the cap rock is "frozen" to the coal, making clean extraction of the coal somewhat difficult.

Bluff Springs mine.—The Bluff Springs mine, locally known as the Blazing Rag, is a small mine now operated by J. T. McLean, of Florence, and located about 2 miles southwest of the town of Coal Creek. Its output, which is small, is hauled by wagon to Florence and neighboring towns. This is the most southerly mine working the Rockvale coal bed, which becomes thin farther south. The coal bed varies in thickness from 3 feet to 3 feet 6 inches in the Bluff Springs mine, including a clay parting 1 to 3 inches thick near the middle of the bed. The clay parting thickens southward to 18 inches at a distance of 2,000 feet from the shaft, the upper bench of coal becoming correspondingly thinner and more dirty until it disappears about half a mile south of the shaft. The lower bench continues with varying thickness at least as far as Radiant, where it is reported to be about 3 feet thick in an old prospect shaft near the tipple of the Radiant mine.

Section of the lower part of the Laramie formation at the Bluff Springs mine.

	Ft.	In.
Sandstone, yellow, with *Halymenites major;* the same bed that outcrops at the top of the Rockvale shaft and back of Williamsburg	40	
Not exposed	40	
Shale, dark, carbonaceous	10	
Coal[a]	2	2
Clay		4
Coal		6
Not exposed, probably mostly sandstone	10	
Sandstone, white, massive	10	
Sandstone, thin bedded	3	
Coal; varies in near-by prospects from 1 foot 8 inches to 2 feet 4 inches	2	
Rock not exposed, lying above the top of the air shaft	25	
Gravel, recent wash at the top of the air shaft	15	
Coal		7
Sandstone and shale	24	
Coal		8
Shale and thin-bedded sandstone	10	
Coal		6–8
Shale	5	
Sandstone	10	
Coal	1	6
Sandstone, hard, concretionary	3	
Shale, dark	12	
Coal	1	6
Shale		2
Coal	1	8
	226	7

The lower 80 feet of this section was measured in the new air shaft sunk in 1908. The rest of the section was measured on the surface.

Radiant mine.—The Radiant mine of the Victor Fuel Company is located in the western part of sec. 7, T. 20 S., R. 69 W. It is on a 3-foot coal bed whose position is estimated to be between 200 and 250 feet above the Rockvale bed, which is not workable near Radiant nor farther south. In the Radiant mine the thickness of the coal bed varies from 3 feet to 3 feet 9 inches. A section of the coal in the northern part of the mine is shown below:

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[a] At another prospect 700 feet north-northwest of the Bluff Springs mine this coal is in one bench measuring 3 feet 10 inches in thickness.

Section of coal bed in the Radiant mine.

	Ft.	In.
Shale.		
Coal	1	4
Shale		0–2
Coal	1	11
Shale.		
	3	4

Mining machines are used to undercut the coal, which breaks free from the roof when shot except in the tenth north entry, where it does not part readily from the roof, or in the miner's phraseology, is "frozen." The coal breaks down in long blocks 4 feet wide, 3 feet high, and sometimes 20 feet long when several holes are fired together. The blocks are usually 7 feet to 8 feet long for single shots.

Joints are strongly developed in the coal bed. The faces trend N. 47° W. and are from 1 to 1½ inches apart. The butts trend N. 50° E. and are 1½ to 3 inches apart. In the tenth north entry there is rude columnar jointing at the top of the coal bed. The columns are about 2 inches across and penetrate the coal for about 6 inches. They are very irregular in cross section. The origin of these joints is not known, but they are possibly due to weathering, although the coal is about 100 feet below the surface in this entry. No igneous intrusions have been noticed in this neighborhood.

Mining operations in the Radiant mine follow a combination of room-and-pillar and long-wall systems. The room-and-pillar method is used for a short distance on either side of the main slope, beyond which the coal is removed by the long-wall method. The coal is all undercut with electric machines, the mine being equipped with five Sullivan long-wall machines and one Jeffrey chain-breast machine. The machine men receive 7 cents a linear foot for undercutting. The loaders are paid 45 cents a ton. After the coal is loaded the mine cars are pushed to the main slope and there hooked to a cable that is drawn by an electric drum to the tipple, about one-fourth mile east of the mine mouth. The tipple is equipped with a steel automatic dump and shaker screens. It has one Westinghouse box-car loader. In the mine there is very little gas, and safety lamps have never been needed. Good ventilation is secured by a furnace at the foot of an air shaft in the southern part of the mine.

The coal appears to be softer and breaks much more easily than that in the northern part of the field. It also slacks more rapidly. Lump coal that had been piled in the open air at the Radiant mine for about three months in 1908 had begun to slack so badly that the miners reported that only about half of the original amount of lump coal could be obtained from the pile. The weathering of these lumps makes the cubical cleavage much more prominent than it is in the fresh coal. As many as six or eight strong joints to the inch appear. In the fresh coal the cubical cleavage can scarcely be distinguished.

The coal bed has an average westward dip of about 2° 15′. In the lower part of the mine the dip is in general about 2° and in the upper part about 3°, but there is much variation, produced apparently by broad open folds or "rolls" in the coal bed. These rolls cause alternate changes in dip of only about 1°, yet they are very noticeable on traveling up the slope. The dip at the end of the slope in 1908 was 2° W. In passing eastward from this point up the slope, dips of 1°, 3°, 2°, and 3° were successively encountered. As in all the rest of the eastern margin of the coal field, the coal bed dips most steeply at the mouth of the mine. This steepening of the dip near the outcrop is probably due to the weathering and expansion of the underlying beds, which are principally shale. It is very noticeable in the southern part of the field, where it is clearly not due to folding, because the line of steeper dips follows the front of the mesa, running up the gullies and around the points with the outcrop of the coal bed.

Shaw prospect.—A small amount of coal has been taken from a slope running eastward on the Radiant bed about one-fourth mile south of the Radiant mine. The entrance to this slope is on the east side of the creek that passes the entrance to the Radiant mine. Coal was hauled away by wagon previous to 1881, when the opening was closed. No further information about this prospect could be obtained at the time of the writer's visit.

Brilliant mine.—The Brilliant mine of the Diamond Coal Mining Company is located in sec. 25, T. 20 S., R. 70 W. It is operated by J. Walton and John D. Lloyd, of Canon City. The coal is hauled to Radiant by wagon and there loaded on railroad cars. The production is about 12 or 15 tons a day.

The coal bed, of which sections are given below, occurs in the upper part of the productive strata, probably at nearly the same horizon as the Brookside bed. It strikes N. 20° E. and dips 9° NW.

Sections of coal bed in the Brilliant mine.

Section 200 feet southwest of foot of shaft.

	Ft.	In.
Sandstone.		
Shale	1	2
Coal, dirty		2-10
Coal	4	6
Coal bed	5	

Section 100 feet southeast of foot of shaft.

	Ft.	In.
Sandstone.		
Shale		6
Bone		1½
Coal		5½
Bone		6
Shale		1
Coal	4	8
Coal, slightly bony		2
Coal bed	6	

The "draw slate" is removed in mining and the sandstone used as roof, which makes the rooms about 7 feet high. The top coal, 1 to 3 feet thick, is not quite clean but makes a satisfactory fuel for a steam boiler. In mining it is separated easily from the rest of the coal and is used in the operation of the mine. This top coal has a dull luster, doubtless due to its high ash content. (See analysis No. 6378, p. 374.) The rest of the coal bed, which varies in thickness from 4 feet 6 inches to 5 feet, is of a uniformly brilliant luster except for a number of dull layers, not over one-eighth of an inch thick.

The coal breaks readily along the bedding planes, a feature not observed elsewhere in this field. The faces trend N. 50° W. and are about 1 inch apart; the butts trend N. 30° E. and are 2 to 4 inches apart. Neither set appears to be very regular either in trend or in spacing.

The mine is operated by a small one-compartment shaft 96 feet deep, equipped with a steam hoist. A coal bed 2 feet 6 inches thick was penetrated by the shaft at a depth of 9 feet. The coal checks more rapidly in weathering than that of the mines in the northern part of the field. Although it does not keep quite so well as the latter, the coal of the Brilliant mine may be kept in stock several months without noticeable deterioration and is said to be a satisfactory domestic fuel.

Mountain mine.—The Mountain mine is a prospect shaft located near the middle of sec. 31, T. 20 S., R. 69 W. The mine is said to be completely caved in, having been idle for fifteen years, and therefore it was not visited. It is reported that about 9 feet of coal was present in this mine, the upper 2 feet being very dirty.

Chandler mine.—The Chandler mine of the Victor Fuel Company is located in the town of Chandler, near the southeast corner of sec. 22, T. 19 S., R. 70 W. It is on a coal bed, in the upper part of the Laramie formation, which lies from 75 to 100 feet below the Brookside bed and which is probably equivalent to the coal at the bottom of the Littell shaft in sec. 16. Typical sections in the eastern and south-central parts of the mine are shown below:

Sections of coal bed in Chandler mine.

Eastern part.

	Ft.	in.
Sandstone.		
Shale	0-3	
Coal	4	
Bone binder which does not break from coal		6
Coal	1	2
Coal bed	5	8

South-central part.

	Ft.	in.
Shale.		
Coal	3	6
Bone		1
Coal	1	4
Coal bed	4	11

The local thinning out of the shale overlying the coal appears to be due mainly to a slight erosional unconformity of the sandstone roof. In most parts of the mine there are "sand rolls" or long lines along which the sandstone cuts down through the "draw slate" and into the underlying coal. In places these sand rolls cut several feet into the coal and at one point a roll touches the bottom of the coal bed, the coal having been entirely removed at that point by erosion in the Laramie period. The sand rolls have round bottoms and curved sides, with no indication of sharp channeling. They trend northeastward in all parts of the mine. Some of them are several hundred yards long, but most of them are only a few hundred feet long. The width of the rolls varies from 10 to 30 feet. The shorter ones hang down in the workings of the mine very much like round-bottomed boats with broad ends. It seems probable that these sand rolls mark the position of stream channels that existed at a time immediately after the deposition of the "draw slate" over the coal. The cross-bedding in the rolls indicates that the streams flowed in a general northeastward direction.

In the northern part of the mine several small faults have been encountered. In the eighth entry west from the main north slope there is a small fault trending N. 10° E. This fault has a downthrow of 4 to 5 feet on the east side. In the seventh entry west off the main north slope there is a small fault which trends east and west and is downthrown 3 feet on the north side.

The room-and-pillar system is used in the Chandler mine, the rooms being driven with widths of 30 to 45 feet. The shale roof clings to the overlying sandstone and the coal breaks sharply from the shale when shot. Very large blocks are shot down in mining as described on page 84. Most of the coal is undercut with Sullivan electric chain cutters. The miners receive $1.05 a ton for hand mining. The two men on the cutting machines receive 5 cents and 4 cents a linear foot. The loaders from the machines are paid 40 cents a ton.

Great Western mine.—The shaft of the former Great Western Coal Company, commonly known as the Cuckoo mine, is located almost on the axis of the sharp flexure on the western margin of the field, in sec. 27, T. 19 S., R. 70 W. On account of this peculiar position with reference to the structure, the shaft penetrates horizontal rocks that are nearly vertical in the entries 300 to 470 feet west of it. In 1908 the mine was idle and in the hands of a receiver, but Mr. L. Lewis, who was temporarily in charge, kindly led the writer through the long crosscut that has been driven for 470 feet westward, across the strike of the upturned beds. The coal beds all appear to be considerably crushed by the upturning of the strata, and the condition of the tunnel was such that most of the rocks could not be satisfactorily measured without the expenditure of unwarranted time and risk of accident. The stratigraphic section of the steeply inclined rocks in this crosscut is approximately as follows:

Section of strata in the old crosscut of the Cuckoo mine.

	Ft.	In.
Sandstone	50	
Coal	1	5
Shale	2	
Coal	1	10
Shale	2	
Rock, mostly shale	50	
Coal	1	6
Shale	1	1
Coal	2	1
Rock, mostly sandstone	25	
Coal	2	3
Sandstone, with some shale	8	
Coal	1	1
Bone		5
Shale, dark	70	
Coal	1	11
Sandstone	10	
Shale	5	
Coal	1	2
Sandstone	5	
Shale	20	
Coal	3	2
Shale		4
Coal		5
Sandstone, with shale partings	30	
Coal, badly crushed in shale, measuring 2 to 4 feet, average probably	2	6
Shale	15	
	313	2

The shaft penetrates the upper part of the same rocks, but the coal beds are thicker in the shaft, according to the following section, taken from a blueprint kindly furnished by Mr. C. L. Mitten, the company's engineer:

Section of strata in the shaft of the Cuckoo mine.

	Ft.	In.
Sandstone	157	
Coal, average thickness	3	
Rock, mostly sandstone	140	
Coal	3	6
Rock, mostly shale	29	
Coal, average thickness	6	
	338	6

This mine has a steam hoist, electric fan, and modern tipple. It is connected by a short spur with the railroad track at Chandler. The mine has recently passed through a receivership and the new purchasers are said to be preparing to reopen it.

Diamond mine.—The Diamond mine is a small one-compartment inclined shaft 240 feet deep located on a nearly vertical coal bed one-fourth mile east of the southwest corner of sec. 17, T. 19 S., R. 70 W., about 4 miles south of Canon City. It is owned by A. C. Dickerson, of Canon City, and operated under lease by Lewis, McCloud, Kingston and Gunn. The average production in November and December, 1908, is said to have been 75 tons a month.

The coal bed varies in thickness from 3 feet to 3 feet 6 inches. The following section was measured near the bottom of the shaft:

Section of coal bed in Diamond mine.

	Ft.	In.
Shale.		
Coal	1	2
Shale		¼
Coal	2	2
Coal bed	3	4¼

The coal dips about 75° E. in the upper 100 feet of the shaft, and about 55° E. in the lower 140 feet. It is probably the same bed as the one at the Nonac or No. 5 mine, but the absence of surface exposures between the two mines makes reliable correlation impossible. The operators report that there is about 2 feet of coal in an old prospect shaft about 75 feet west of the mine. It is possible that the coal in this prospect is a lower bed. In a crosscut driven eastward, across the strike, from the Diamond mine 2 feet 6 inches of coal was encountered at a distance of 90 feet. If the 75° dip observed at the shaft prevails across this distance the stratigraphic position of the three beds is approximately as follows:

Section at Diamond mine.

	Ft.	In.
Coal, in crosscut, reported	2	6
Rock	72	
Coal, in Diamond mine	3	4
Rock	87	
Coal, in prospect shaft, reported	2	
	166	10

The coal in this mine is hard but locally crushed. It shows in places a marked development of joints, which make lozenge-shaped patterns when viewed in horizontal cross section of the nearly vertical bed. The acute angles of these lozenges, measuring 20° to 35°, lie in the direction of the strike and the supplementary obtuse angles lie in the direction of the dip. Some of the joints are slickensided. They are evidently the product of the same compressive shear that upturned the strata of the western margin of the field. The superposition of the lozenge joints on other sets of joints running more nearly parallel to the directions of strike and of dip makes the joints very intricate where both sets are developed. This is in marked contrast to the simple joints in the mines located in nearly horizontal strata already described.

Royal Gorge mines.—The Royal Gorge Coal and Fireclay Company operates two inclined shafts on an upturned coal bed about 3 miles south of Canon City. The mines have a combined annual production of about 65,000 tons, most of which is shipped by rail from No. 2 mine. No. 1 mine, one-fourth mile north of No. 2, ships its coal by wagon for local use only.

In the Royal Gorge mines there are two coal beds about 7 feet apart which are mined together. A typical section in mine No. 2 is shown below:

Section of coal beds in Royal Gorge mine No. 2.

	Ft.	In.
Sandstone.		
"Draw slate"	2	
Coal	4	
Sandstone, fine, and hard shale	7	
Coal	3	8

The upper bed is said to measure 5 feet 4 inches in mine No. 1, and the lower bed to measure 4 feet 6 inches in Alkali Gap, but these statements could not be verified owing to the inaccessibility of the old workings. A good coal bed 4 feet 6 inches thick, located about 165 feet stratigraphically above the Royal Gorge beds, was penetrated at a distance of 206 feet in a crosscut running 283 feet eastward across the strike from No. 2 mine. The following section was made in this crosscut:

Section of strata in crosscut east from Royal Gorge mine No. 2.

	Ft.	In.
Rock, mostly sandstone	55	
Coal, including a 4-inch clay parting	4	6
Sandstone	20	
Shale	15	
Coal	1	2
Shale, said to be fire clay	8	
Sandstone, white, massive	120	
"Draw slate," above the Royal Gorge coal	2	
	225	8

Another section of the same coal bed, measured 100 feet south of the crosscut, is as follows:

Section of coal bed in level from crosscut east from Royal Gorge mine No. 2.

	Ft.	In.
Sandstone.		
Shale	1	
Coal	2	6
Shale		3
Coal	1	2
Shale	2	5
Sandstone.		
Coal bed	3	11

About 200 feet west of the Royal Gorge bed Mr. Bettis has sunk a prospect shaft 95 feet deep in which a bed of coal 3 feet thick is said to have been struck at a depth of 75 feet. This is presumably the Nonac bed.

The method of working the two coal beds in the Royal Gorge mines is interesting, because the beds are separated by only 5 to 7 feet of rock of moderate strength, of which more than half is firm shale and the remainder is sandstone in beds 5 to 12 inches thick. The strata dip 50° E. In spite of these apparently unfavorable conditions the coal is remarkably free from dirt, as reported in analyses made for the power plant of the Arkansas Valley Electric Company at Canon City, and as shown by about 9 per cent of ash in the analysis of a car sample of the pea and slack coal (No. 6248).

The method of mining may be described as follows: From the main incline nearly horizontal levels are driven along the coals at about every 90 feet of depth. The coal is removed by upward stoping and drops through chutes into the mine cars on the levels. About 8 feet of coal is left temporarily as a roof to protect the levels. Black powder is used principally, with a small amount of giant powder in hard rock work. The lower coal bed is removed first and the thick parting of rock is allowed to settle into the stope, which it does slowly, breaking free from the bottom of the upper coal, which is then mined by the same method. No rock needs to be hauled to the surface except that removed in driving the levels. In 1908 the fifth level was being driven, at a depth of about 450 feet. The relative percentages of products obtained are: Lump coal, 40 per cent; nut coal, 25 per cent; pea and slack, 35 per cent.

Hayes mine.—The abandoned Hayes mine, located about one-fourth or one-half mile north of the Royal Gorge mines, probably worked the same coal bed. It was operated in the early days and the coal was hauled by wagon to Canon City. It is now completely caved in, and no information about it could be obtained.

Nonac mine.—The Nonac mine of the Colorado Fuel and Iron Company is located in Canon City, on the south side of Arkansas River. It is commonly known in the locality as No. 5, because it bore that number when operated by the Canon City Coal Company in the early days of this field. It is now No. 39 in the list of the Colorado Fuel and Iron Company. The mine is one of the oldest in the field, having been opened by Mr. Thornton in 1883.

The Nonac mine is worked from a slope running about half a mile to the southeast at an inclination of approximately 12°. The dip of the rocks at the mouth of the slope is 23° SE., but this high dip decreases within a short distance to 12°, which prevails throughout most of the mine.

The coal is the lowest workable bed in this locality, but it is about 70 feet above the Rockvale bed, which was cut through at the mouth of the slope but is worthless in this part of the field. The Nonac bed varies in thickness from 5 feet 8 inches to 6 feet 2 inches, except in the northern margin of the workings, where the coal is only 4 feet thick and contains a shale parting 10 to 12 inches thick near its middle. This parting wedges out toward the south and at a distance of one-fourth mile is represented by only a quarter of an inch of shale. Northeastward it thickens to 15 feet at the Prentiss shaft.

The mine employed about 90 men and produced about 300 tons a day before it was closed in December, 1907. The product was made up of lump coal, 55 per cent; nut coal, 20 per cent; pea and slack, 25 per cent. The mine is equipped with a steam 50-horsepower hoist, steam fan, wood tipple, stationary screens, and two electric mine pumps. At the time of the writer's visit in 1908 the mine was ventilated and kept in readiness to be reopened.

The coal from the Nonac mine is comparatively hard and stocks remarkably well. A large block of this coal several feet high has been standing exposed to the weather in front of a coal office in Canon City for sixteen years. (See p. 375.)

Prentiss shaft.—The Prentiss shaft was located near the center of sec. 4, T. 19 S., R. 70 W., about half a mile east of the Nonac mine. It has been abandoned for many years and no trace of it remains on the surface. John Arthur, of Canon City, reports that about 20 or 30 acres of coal was worked out from this shaft in 1888 and 1889, and that the coal bed was about 4 feet thick, becoming bony in the northern part of the mine. The mine had a good sandstone roof. The coal bed is 10 to 15 feet above the Nonac bed and is thought to be the upper bench of that bed, separated by the increased thickness of the parting which was noticed near the middle of the bed in the Nonac mine.

Littell mine.—The Littell mine, in Wolf Park, 3 miles southeast of Canon City, is operated by the Colorado Central Coal and Mining Company, under the control of the Littell Brothers Coal Mining Company, of Colorado Springs. The shaft is located in the deepest part of the coal basin and has a depth of 1,065 feet, which is not exceeded by any other coal shaft in the State. The mine is on a bed of good clean coal 5 feet 6 inches to 5 feet 10 inches thick, probably the same bed which is mined at Chandler and which is exposed in an open cut in Alkali Gap, where considerable impurity is present. (See section, p. 358.) In 1908 mining operations were curtailed, awaiting the completion of a spur from the railroad. The following section of the rocks was kindly furnished by the miners who sank the shaft:

Section of rocks in the shaft of the Littell mine, Wolf Park.

	Ft.	in.
Sandstone, with blue pebbles	80	
Conglomerate	10	
Sandstone and conglomerate	110	
Conglomerate, mostly	100	
Sandstone and conglomerate in layers	250	
(Total Arapahoe (?) conglomerate, 550 feet.)		
Sandstone	100	
Clay	40	
Sandstone, solid	100	
Sandstone, with clay partings	80	
Coal		3
Sandstone, mostly	45	
Coal	1	6
Sandstone (?)	12±	
Shale	25	
Sandstone	2	6
Shale	3	6
Coal, probably Brookside bed	2	
Bone		3
Sandstone	22	
Shale	2	
Coal		10
Shale	5	
Sandstone	45	
Sandstone, very hard, "quartzitic"	2	
Sandstone and shale	7	
Sandstone	6	
Shale	9	
Coal, probably Chandler bed	5	8
	1,065	6

The strike of the rocks at the bottom of this shaft is north and south; the dip 5° W. The shaft is equipped with a 75-horsepower steam hoist and an electric pump with a capacity of 100 gallons a minute. About 2,000 gallons of water an hour was entering the shaft in July, 1908, mainly from the upper sandstones and conglomerates. A little water also enters from the joints in the roof of the coal bed, but not in sufficient quantity to cause trouble. It is probable that when the water that enters the shaft from the upper sandstones is cased off there will be little trouble from this source.

At the time of the writer's first visit to this mine, in July, 1908, the shaft had reached a coal bed at a depth of 950 feet and prospect drifts had been extended on the bed for several hundred feet because it was thought to be the Rockvale bed, which is the lowest coal of this field. But on comparison of the foregoing section with the section measured in Alkali Gap (pp. 345-346), it became apparent that the prospect entries were being driven on a bed (the Brookside ?) that lies over 400 feet above the Rockvale bed and about 75 or 80 feet above the Chandler bed, which has an excellent development 2 miles north and 1 mile west of the mine. The Chandler bed was then sought by drilling and was encountered at a depth of 98 feet below the Brookside (?) bed. Those who now believe that the bed being worked at present in the Littell shaft is the Rockvale bed would do well to compare the section in the shaft with that in Alkali Gap. It will appear from this comparison that the Rockvale bed in the center of sec. 16 has a depth of about 1,450 feet, unless the rocks change considerably in thickness east of the gap. The Rockvale bed probably reaches a maximum depth of about 1,500 feet in the southwestern part of Wolf Park, which, therefore, must be either a deep syncline or a downfaulted block. A few east-west step faults, downthrown on the north side, have been encountered in the northern part of the Chandler mine. If more of these faults, or one large fault of the same kind, intervene between the Chandler workings and the Littell shaft, they may explain the discrepancy in depth of the Chandler bed in the two mines. In the imperfect exposures of Arapahoe (?) conglomerate that cover the intervening country no faults could be found. The dips fail by about 150 feet to explain the difference in depth. Dips determined in the conglomerate, which was laid down on stream beds that may have had an initial slope of 5° or more, are not satisfactory, and the true correlation of these beds must be ultimately determined by mining operations. Thus, on the east side of Wolf Park the bedding planes in the conglomerate dip 12° W. This conglomerate was laid down as coarse gravel by streams flowing eastward from the mountains. If the gravel beds had an initial slope of 5° E., like many of the deposits in the existing creeks, the conglomerate must have been tilted westward through an angle of 12° plus 5°, or 17°. The coal beds would dip 17° W. under these conditions, thereby explaining most of the discrepancy in depth between the coals in the Littell mine and those east of Wolf Park. Failure to appreciate this structure and the fact that the overlying barren measures are nearly 1,000 feet thick in Wolf Park has caused the abandonment of prospect drilling in this locality several hundred feet short of the most valuable coal bed.

No sample for analysis was collected from the main bed at the Littell mine, but a sample was obtained of the upper (Brookside ?) bed and the analysis (No. 6257) is given on page 373.

Brookside mine.—The Brookside mine of the Colorado Fuel and Iron Company is located in sec. 11, T. 19 S., R. 70 W. It is one of the oldest and was once the largest producer in the Canon City coal field. Its product was well known and in high demand in Colorado. The mine was opened over twenty years ago and produced about 1,000 tons a day for several years, but the output was later allowed to fall to 250 tons a day, when the company developed other mines in which the cost of production was less. Since January 28, 1908, the mine has been shut down, and at the time of the writer's visit in the succeeding summer the workings were rapidly filling with water. For this reason and for lack of ventilation it was impossible to enter the mine, hence all of the information obtainable was that derived from mine maps and from the miners left in charge of the property.

The coal is the highest workable bed of the Canon City field. The operators report that throughout most of the mine the bed averages 5 feet 6 inches to 6 feet in thickness, but becomes thin and dirty at the south end of the mine, about a mile from the entrance. At the southwest end of the mine there is 3 feet of coal, and at the west end, east end, and center the sections are as follows:

Sections of coal bed in Brookside mine.

West end of mine.	Ft.	In.
Coal		9½
Bone		2½
Coal	4	1
Coal bed	5	1

East end of mine.	Ft.	In.
Coal		2
Bone	1	
Coal	3	
Coal bed	4	2

Central part of mine.	Ft.	In.
Sandstone.		
Shale	½–2	
Coal		6
Bone		2
Coal	6	
Coal bed	6	8

In mining the lower coal breaks from the bone, which is left as roof. The coal dips south-southwest, the angle of dip gradually decreasing down the slope. For the first 1,000 feet in from the entrance the dip is about 8 per cent, and for the next 4,000 feet it is about 6 per cent. The abandonment of the mine is thought to be permanent, as nearly all the coal that can be extracted profitably from this slope is said to have been removed.

Brewster mine.—The Brewster mine covered about 80 acres of coal of the Rockvale bed in the NW. ¼ sec. 18, T. 19 S., R. 69 W. It has been idle for about ten years and the workings are completely caved in. No measurement of the coal bed could be obtained, but it is reported that the thickness varied from 3 feet 6 inches to 4 feet in the eastern part of the mine and was about 2 feet 6 inches in the northwestern part.

Magnet mine.—The Magnet mine of the Rocky Mountain Fuel Company, often called the Ocean Wave mine, is located near the center of sec. 19, T. 19 S., R. 69 W. In 1908 it was shipping about 200 tons a day. It is on a 3 to 4 foot coal bed, which is the first coal above the Rockvale bed on the east side of the field, the Nonac bed being absent except in the northwestern part of the field. At the end of the main slope in 1908 the coal was 4 feet thick, including two or three clay partings about one-eighth inch thick. In the sixth east room off the third south entry the following section was obtained:

Section of coal bed in Magnet mine.

	Ft.	in.
Sandstone.		
Shale	1	9
Coal	3	5
Shale.		

In the main south entry 400 feet from the main slope the coal bed measured 4 feet 3½ inches, as shown below. The middle parting thickens northwestward in the mine, as shown by the section measured on the face of the third south entry from the main slope.

Sections of coal bed in Magnet mine.

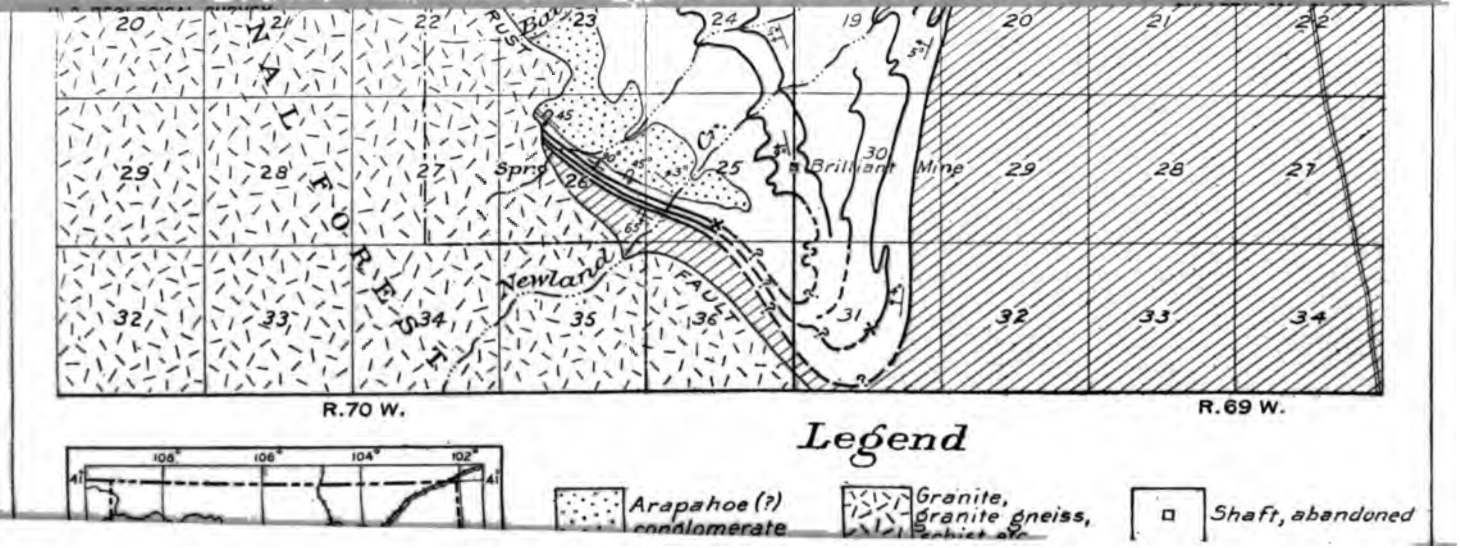
Main south entry.	Ft.	in.	Third south entry.	Ft.	in.
Coal	2	2	Coal	2	3
Shale		3½	Shale		4
Coal	1	10	Coal	1	11
Coal bed	4	3½	Coal bed	4	6

The parting is said to increase in thickness and in coarseness of grain to the northwest, becoming 2½ feet of sandstone at the northwest end of the mine. Three sets of joints were observed in the coal in this mine. The two strongest sets trend N. 60° W. and N. 30° to 45° E. The former are 2 to 3 inches apart and the latter about 1 inch apart. A minor set of weak joints trending N. 30° W. was observed at a few places. The miners believe that the coal picks easiest on the east-west faces.

About half the coal is machine mined. Three Sullivan electric chain-breast machines are used. For hand mining in 1908 the miners received 90 cents a ton. Considerable giant powder is necessary in many parts of the mine owing to the hardness of the coal, to the tightness with which it clings to the roof and floor, and to the local abundance of hard "niggerheads." This is probably one of the causes for the low percentage of lump coal obtained. The relative proportions of the product are: Lump, 51 per cent; nut, 19 per cent; slack and pea, 30 per cent.

The mine is worked from a slope running westward down the dip of the bed. As in all the slopes starting from the eastern outcrop of the coal, the inclination is greater near the surface than it is farther down the slope. In the Magnet mine the dip is about 13° W. for the first 300 feet and then changes rapidly to 5° W. and finally to 4° W. in the last 900 feet of the slope.

The room-and-pillar system had been followed up to the summer of 1908, when the long-wall system was adopted, because its use in the other mines of the field has fully demonstrated that it results in a saving of 15 to 40 per cent on mine timber and in a considerable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NAL FOREST
RUST
Bar
Spr
Cr.
Brilliant Mine
Newland
FAULT
45
45
45
65
R.70 W.
R.69 W.
108°
106°
104°
102°
41°
41°
Legend
Arapahoe (?) conglomerate
Granite, granite gneiss, schist etc.
Shaft, abandoned

increase in the percentage of lump coal obtained, owing to the absence of crushing of pillars and to the greater ease of working a long uninterrupted face. In this mine there is locally also considerable "draw slate" and other débris which is most easily disposed of by piling it immediately behind the miners as they advance the long-wall face. Owing to the bad shale roof, heavy timbering was formerly required in the mine.

This mine has little gas and most of that encountered is believed to come from the roof and the top coal. The fire boss reports having observed one small harmless blow of fire damp which came from the top of the coal and which was exhausted in a few hours. As in all the mines of this field, gas has never caused any trouble and safety lamps are rarely required and then only in places of local escape of gas.

The coal bed of the Magnet mine is not exposed at the surface but covered by soil. It is known to extend at least 1½ miles south of the entrance to the mine. North of the mine the bed continues for about the same distance with varying thickness. In the wagon road southwest of the schoolhouse in sec. 12, T. 19 S., R. 70 W., the bed is reported by Simon Smith to be 5 feet thick. Near Mr. Smith's house, in the SW. ¼ SW. ¼ sec. 7, T. 19 S., R. 69 W., the coal is absent and the roof sandstone rests on the stratum beneath the coal. The same condition is reported in an old prospect about one-fourth mile northwest of the Emerald mine. It is probable that the absence of the coal is due to a "sand roll" or local unconformity marking the position of a stream channel of the Laramie epoch.

Walsh mine.—The Walsh mine is a small mine from which coal was hauled by wagon. It is located about one-fourth mile north of the Magnet mine and on the same coal bed. The coal has about the same thickness as in the Magnet mine, but the parting in the bed is sandstone from 12 to 18 inches thick. The opening is said to be utilized at present mainly in drawing old pillars in the northern part of the Magnet mine.

Emerald mine.—The Emerald mine, owned and operated by Simon Smith, is a small mine about a mile north of the Walsh mine and 3 miles west of Florence, in sec. 18, T. 19 S., R. 69 W. The coal, which is probably the Rockvale bed, varies from 3 feet 3 inches to 3 feet 10 inches in thickness, including in places two clay partings each about one-eighth of an inch thick.

The mine is worked from a slope which in 1908 was 550 feet long. The slope is inclined 4° 45′ for the first 300 feet from the entrance and 3° 40′ for the next 250 feet. A similar increase in dip near the surface of the ground has been noted in nearly all the slopes on gently dipping rocks in this field. It is thought to be due in most places to the weathering and expansion of the underlying rocks. The coal is hauled from this mine by wagon.

Willey mine.—The Willey mine is located in the SE. ¼ sec. 18, T. 19 S., R. 69 W. Entries Nos. 1 and 2, which opened on Oak Creek, are now abandoned. Entry No. 4, about one-fourth mile south of No. 2, is in a small gully that trenches the east side of the lower escarpment. None of these mines was large, and all of the coal was hauled from them by wagon, principally for local consumption. No. 3 is now operated by the Florence Fuel Company. It works the Rockvale bed, which has the following thickness:

Section of Rockvale coal bed in Willey mine No. 3.

	Ft.	In.
Sandstone.		
"Draw slate"		2–18
Coal	3	6
Sandstone.		

Santa Fe No. 8 mine.—No. 8 mine of the Atchison, Topeka and Santa Fe Railway Company is located on the steeply dipping western margin of the coal field, about 3 miles west of Rockvale. The mine was a steep incline, with a slope of about 30° E., about 1,000 feet deep, that worked a coal bed at approximately the same horizon as the beds in the Chandler and Littell mines. It has been abandoned for many years and can not be entered. The coal is said to be 4 feet 6 inches to 5 feet thick.

Bassick mine.—The Bassick mine is a steep incline located on the upturned coal strata in the southeast corner of sec. 27, T. 19 S., R. 70 W. It is an old mine, having been opened over thirty years ago. The production was small and all the coal was hauled by wagon, most of it to the Bassick gold mine, on the west side of Wet Mountain. The mine has been idle for many years except during the miners' strike four or five years ago, when a few tons were taken out. The coal bed, which is said to average about 5 feet in thickness and to vary greatly in character, occurs at about the same horizon as the Royal Gorge beds or possibly about 50 feet lower. In 1908 the mine was filled with water and could not be entered beyond a distance of about 50 feet down the slope. At the latter point the following section was measured:

Section of coal bed in the entrance to the Bassick mine.

	Ft.	In.
Shale.		
Coal	1	
Shale		2
Coal	4	
Coal bed	5	2

About 150 yards northwest of the Bassick mine the following section was measured on the east side of Oak Creek.

Section northwest of Bassick mine.

	Ft.	In.
Sandstone, resistant	20	
Shale, sandy in the upper part	10	
Coal, probably Nonac bed, surface measurement	2	1
Shale, carbonaceous, with sandy layers	20	
Sandstone, soft, argillaceous, weathering white	20	
Coal		4
Shale, carbonaceous, probably Rockvale coal horizon	2	
Sandstone, soft, white, argillaceous, weathering into a sandy clay	35	
Sandstone, hard, yellow, thin-bedded, Trinidad sandstone	40	
Sandstone and shale in beds 1 to 4 feet thick with ripple marks and fossil leaves	25	
Shale, Pierre.		
	174	5

Simon Smith shaft.—The Simon Smith prospect shaft was sunk for the purpose of reaching the Rockvale coal bed in the southern part of sec. 36, T. 19 S., R. 70 W. It is said to be 218 feet deep, mainly in sandstone, and to cut one workable coal bed. Work had stopped at the shaft in 1908, because the depth to the Rockvale coal bed was calculated to be 570 feet. Inspection of the strata at this locality makes it seem probable that the depth to the Rockvale coal is less than this, possibly not over 500 feet.

Coal prospect in the Dakota sandstone.—Verne Baumgartel has sunk a small prospect shaft on a coal blossom in the Dakota sandstone on his farm 3½ miles south of Canon City. The bed is from 6 inches to 2 feet thick and stands nearly vertical, between beds of massive sandstone, from which it is separated in places by shale partings that are reported to be fire clay. The coaly substance is hard, black, and crushed by shearing movements along the bedding planes into lenticular, slickensided fragments 1 to 3 inches long. Although these shiny fragments closely resemble hard coal, it is evident from the high ash shown by the following analysis that the material is bituminous shale and probably of no value.

Proximate analysis of air-dried coal from Baumgartel prospect, 3½ miles south of Canon City.

[Laboratory No. 6256.]

Moisture	8.10
Volatile matter	24.55
Fixed carbon	20.91
Ash	46.44
Sulphur	.48
Air-drying loss	8.00

No other indications of coal have been observed in the Dakota sandstone in the Canon City region, although the formation is well exposed and it has been pretty thoroughly prospected for fire clay. A tunnel has been driven through the Dakota hogback at Canon City without encountering coal. Evidently there is no warrant for further efforts to find coal in the Dakota sandstone in this vicinity.

CHARACTER OF THE COAL.

The coal of the Canon City field is well known in the West as a high-grade domestic fuel. Practical tests have shown that it does not coke. When ground in an agate mortar, the powder falls clean from the sides of the mortar and does not adhere to the end of the pestle. This test has been found by M. A. Pishel,[a] of the United States Geological Survey, to indicate the noncoking character of a coal.

The absence of the coking property makes the coal cleaner to handle and therefore more desirable as a domestic fuel, although it would be better for steaming purposes if it had a tendency to coke. The coal is firm and hard and produces comparatively little dust in handling. It has a well-developed system of cubical joints, which are one-eighth to one-fourth inch apart, but the fresh coal does not break along these planes unless struck a hard blow. The coal burns with a short bluish flame under draft and with a slow whiter flame in a stove. Grates of the type commonly used under steam boilers are evidently poorly adapted to this coal, as an unusually dense and abundant smoke issues from the funnels when it is burned under boilers, as may be seen at the works of the United Oil Company in Florence and to a less extent at the Arkansas Valley Electric Company's power plant in Canon City. At the latter plant it is found desirable to mix the slack of noncoking Canon City coal with slack of coking coal from the Trinidad field. By careful regulation of the hand stoking and of the draft the smoke can be considerably reduced, but it is reported that a satisfactory grate has not been found for Canon City slack coal.

The chemical properties and calorific power of some of the Canon City coals will be found by inspection of the following table. Samples were collected from all the mines and sealed in galvanized-iron cans with adhesive tape, but in the writer's ignorance of the rapid deterioriation of coal under such conditions[b] he kept many of these samples for several months after collecting. It is doubtful whether under such conditions an analysis of them would give accurate results or not. It will, therefore, be found that several of the principal mines are not included in the following table. The samples were all collected by cutting a uniform trench across the coal bed, then comminuting the material, mixing, quartering, and rejecting opposite quarters, the last process being repeated until the residue would fill a 3-pound sample can. Partings over half an inch thick were rejected. The cans were sealed within the mines immediately after the samples were collected.

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[a] Econ. Geology, vol. 3, 1908, p. 266.

[b] See Parr, S. W., and Hamilton, N. D., The weathering of coals: Econ. Geology, vol. 2, 1907, p. 693.

Analyses of coal samples from the Canon City coal field, Colorado.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6249	17	19	70	4 6	4 6	8.1	As received	15.0	34.2	45.7	5.08	0.54	5.52	60.76	0.91	27.19	6,024	10,843
							Air dried	7.5	37.3	49.7	5.53	.59	5.03	66.11	.99	21.75	6,556	11,801
							Dry coal		40.2	53.8	5.98	.64	4.53	71.47	1.07	16.31	7,086	12,755
							Pure coal[a]		42.8	57.2		.68	4.82	76.01	1.14	17.35	7,537	13,567
6252	17	19	70	4	4	6.1	As received	12.4	36.7	44.5	6.41	3.03	5.38	61.12	.90	23.16	6,160	11,088
							Air dried	6.7	39.1	47.4	6.83	3.23	5.01	65.09	.96	18.88	6,560	11,808
							Dry coal		41.9	50.8	7.31	3.46	4.57	69.71	1.03	13.92	7,026	12,647
							Pure coal		45.2	54.8		3.73	4.93	75.21	1.11	15.02	7,580	13,644
6253	17	19	70	3 8	3 8	4.5	As received	11.2	36.8	45.7	6.29	.92	5.44	62.50	.96	23.89	6,270	11,286
							Air dried	7.0	38.5	47.9	6.59	.96	5.17	65.45	1.01	20.82	6,565	11,817
							Dry coal		41.4	51.5	7.08	1.04	4.73	70.38	1.08	15.69	7,060	12,708
							Pure coal		44.6	55.4		1.12	5.09	75.74	1.16	16.89	7,598	13,676
6254	22	19	70	4 11	4 1	3.3	As received	9.9	35.3	48.6	6.21	.43	5.10	64.02	.91	23.33	6,357	11,443
							Air dried	6.8	36.5	50.3	6.42	.44	4.89	66.20	.94	21.11	6,574	11,833
							Dry coal		39.1	54.0	6.89	.48	4.44	71.04	1.01	16.14	7,050	12,697
							Pure coal		42.1	57.9		.52	4.77	76.30	1.08	17.33	7,576	13,637
6257	16	19	70	2	2 1	6.2	As received	13.0	33.2	46.4	7.38	.63	5.50	61.46	.90	24.13	6,045	10,881
							Air dried	7.2	35.4	49.5	7.87	.67	5.13	65.52	.96	19.85	6,445	11,601
							Dry coal		38.1	53.4	8.48	.72	4.67	70.63	1.03	14.47	6,947	12,505
							Pure coal		41.7	58.3		.79	5.10	77.18	1.13	15.80	7,591	13,664
6250	17	19	70	4 4½	4 4½	17.2	As received	23.2	30.3	40.2	6.28	.95	6.15	54.62	.79	31.21	5,348	9,626
							Air dried	7.2	36.6	48.6	7.59	1.15	5.12	65.97	.96	19.21	6,459	11,626
							Dry coal		39.5	52.3	8.17	1.24	4.65	71.10	1.03	13.81	6,961	12,530
							Pure coal		43.0	57.0		1.35	5.06	77.43	1.12	15.04	7,581	13,646
6251	5	19	70	6	6	4.8	As received	11.1	33.6	49.9	5.39	.93	5.18	63.67	1.04	23.79	6,347	11,425
							Air dried	6.6	35.3	52.4	5.66	.98	4.88	66.88	1.09	20.51	6,667	12,001
							Dry coal		37.8	56.1	6.06	1.05	4.44	71.60	1.17	15.68	7,138	12,848
							Pure coal		40.3	59.7		1.12	4.73	76.22	1.25	16.68	7,598	13,676

[a] "Pure coal" is used to indicate the hypothetical condition of the coal when all its moisture and ash are removed. It is not strictly correct, as the sulphur has not been eliminated but owing to the briefness and convenience of the term it is used in this report as noted above.

Analyses of coal samples from the Canon City coal field, Colorado—Continued.

Laboratory No.	Location.			Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Sec.	T. S.	R. W.	Coal bed.	Part sampled.			Moisture.	Volatile matter.	Fixed carbon	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
				Ft. in.	*Ft. in.*													
6376	25	19	70	3 8	4	0.6	As received	5.5	38.0	44.4	12.10	0.72	5.52	64.05	1.09	16.52	6,600	11,880
							Air dried	4.9	38.2	44.7	12.18	.72	5.48	64.44	1.10	16.08	6,640	11,952
							Dry coal	....	40.2	47.0	12.80	.76	5.20	67.73	1.15	12.36	6,980	12,564
							Pure coal	....	46.1	53.9	....	.87	5.96	77.67	1.32	14.18	8,005	14,409
6377	25	20	70	5 4	(*a*)	3.0	As received	13.0	31.5	53.2	2.26	.73	5.39	65.09	.80	25.73	6,303	11,345
							Air dried	10.3	32.5	54.9	2.33	.75	5.22	67.10	.82	23.78	6,498	11,696
							Dry coal	....	36.3	61.1	2.60	.84	4.54	74.80	.92	16.30	7,243	13,037
							Pure coal	....	37.2	62.8	....	.86	4.66	76.80	.94	16.74	7,436	13,385
6378	25	20	70	5 4	*b* 10	1.9	As received	9.1	31.7	36.6	22.61	.48	5.09	51.33	.93	19.56	5,163	9,293
							Air dried	7.3	32.3	37.3	23.05	.49	4.97	52.32	.95	18.22	5,263	9,473
							Dry coal	....	34.9	40.2	24.86	.53	4.49	56.44	1.02	12.66	5,677	10,219
							Pure coal	....	46.4	53.6	....	.71	5.98	75.11	1.36	16.84	7,556	13,601
6379	25	20	70	5 4	4 6	2.9	As received	11.2	34.8	44.1	9.88	.51	5.28	59.94	1.02	23.37	5,961	10,730
							Air dried	8.5	35.9	45.4	10.18	.53	5.11	61.73	1.05	21.40	6,139	11,050
							Dry coal	....	39.2	49.7	11.12	.57	4.55	67.46	1.15	15.15	6,709	12,076
							Pure coal	....	44.1	55.9	....	.64	5.12	75.90	1.29	17.05	7,548	13,586
6409	6	20	69	3 4	3	6.5	As received	10.3	32.7	42.7	14.29	.54	5.26	58.09	1.05	20.77	5,813	10,463
							Air dried	4.0	35.0	45.7	15.28	.58	4.86	62.13	1.12	16.03	6,217	11,191
							Dry coal	....	36.5	47.6	15.92	.60	4.59	64.72	1.17	13.00	6,476	11,657
							Pure coal	....	43.4	56.6	....	.71	5.46	76.97	1.39	15.47	7,702	13,864

[a] Bright layers.

[b] Dull top coal.

6249. Royal Gorge mine No. 2, 3 miles south of Canon City. Sample from upper bed in crosscut from level No. 5.

6252. Same. Sample from middle bed on level No. 6. Sample wet.

6253. Same. Sample from lower bed on level No. 6, south side of main entry. Sample wet.

6254. Chandler mine, 6 miles southeast of Canon City. Sample from room No. 1, Cuckoo entry. Sample dry.

6257. Littell mine, 3½ miles south-southeast of Canon City. Sample from upper bed in first entry south, 100 feet from foot of shaft. Sample wet.

6250. Diamond mine, 3½ miles south of Canon City. Sample from level No. 2.

6251. Nonac mine, locally known as No. 5, 2 miles south of Canon City. Sample from working face 2,600 feet east of mouth of mine. Sample wet.

6376. Rockvale mine, Rockvale. Sample of 4 inches of hard greasy coal resembling cannel at top of bed in fourth dip in fourth north entry.

6377. Brilliant mine. Sample of bright, shiny layers, particularly abundant in top, bony coal.

6378. Same. Sample of dull top coal.

6379. Same. Sample of main part of coal bed.

6409. Bluff Springs mine, locally known as Blazing Rag, 2 miles south of Rockvale.

The coal of the Canon City field stocks unusually well. It may be kept for several years without much slacking, but of course, as in all coals, some deterioration sets in as soon as the coal is exposed. This is said to be less noticeable in the Canon City coal than in most western coals. The coal is not liable to spontaneous combustion, as attested by the large unburned slack piles at several places. In the mine dumps it catches fire and burns slowly for years. Parts of old dumps which have been abandoned for several years are still warm from the slow combustion of the coal.

A good example of the keeping quality of the Canon City coal is a large block of the coal which stands in front of Mr. Rockefellow's retail coal office in Canon City. This block, which was obtained from the Santa Fe mine No. 5, now the Nonac mine, had, according to report, been standing as an advertisement beside the street curb for sixteen years, protected from the weather only by a sheet of tin laid on its upper surface. The block was originally 5 feet high, this dimension being the thickness of the coal bed from which it was obtained, and 4 feet square on the base and top. When the writer examined the block in 1908 its height was still 5 feet, but it had lost from 6 to 8 inches from each side by spalling. Cubical checking was developed all over the surface of the block and two large cracks had cut nearly through it, necessitating a narrow band of iron around the block to prevent it from falling apart. The surface of the coal was somewhat dulled by the weather, but it was still black, without any whitening from the appearance of ash or the deposition of sulphur compounds.

The statements about the keeping quality of the Canon City coal apply with minor variations to the coal beds in the greater part of the field, from the lowest or Rockvale bed to the highest or Brookside bed. They do not apply so well to the coal of the southern part of the field, which is inferior in keeping quality. A large pile of coal at the Radiant mine, which had been exposed to the air for about four months in 1908, was slacking badly and deep checks had developed in the lump coal. About the lumps of coal there was much fine débris which had fallen from their surfaces. The miners stated that lump coal amounting to half of the lump coal originally in the pile could be obtained from it after this exposure to the weather. The Radiant coal bed is in the lower part of the Laramie formation, at an estimated distance of 200 to 250 feet above the Rockvale bed at the base of the formation. The cause of this slight inferiority of the coal from the south end of the field is not known. The coal is apparently not quite so hard as that from the north end of the field, but in jointing it is not noticeably different from the latter. The blocks cut down in mining at the south end of the field are considerably smaller than similar blocks in the northern mines. The coal seems to break much more easily along the bedding planes and also along the joint planes, but other factors may also enter into the problem. The writer does not intend to state that the coal of the southern part of the field is not a high-grade domestic fuel, but that it is not quite so good in keeping or weathering quality as most of the coal of this field.

There is considerable difference in the size of blocks cut down in mining in the different mines, owing partly to variance in mining methods and partly to inequality in the strength of the joints. Along the steep-dipping western limb of the syncline, from the Royal Gorge mine southward, intricate sets of closely spaced cross joints, meeting at acute angles, have been developed from the greater strain which the rocks have there undergone. In a few places the coal on the west side of the field is slickensided and crushed, but as a rule the joints show no evidence of slipping. Along this belt of nearly vertical and overturned beds large blocks of coal can not be obtained. The method of overhead stoping, required to work the steep beds, also lowers the percentage of lump coal obtained and increases the slack. Throughout the greater part of the field, however, the beds are nearly flat, dipping at angles of 2° to 5°, and large blocks are cut down in mining. In the Chandler mine the writer observed a block of coal which had just been undercut and shot down that had the following dimensions: Height, 4 feet 1 inch, being the full thickness of the bed at that place; width, 3 feet; length, 18 feet. This block was too large for handling, but by using wedges it was broken into smaller blocks. It well exemplifies the strength of the coal. Similar blocks of smaller size are the rule in most of the mines. Shooting is always necessary, as it is difficult even to cut a small channel across the coal in obtaining samples. As a result of the strength and hardness of the coal and of the difficulties with which it is broken along the wide-spaced rectangular joints, the percentage of lump coal obtained in most of the mines is large. In the northern part of the field the range in sizes of coal from gently dipping beds is as follows: Lump coal, 45 to 70 per cent; nut coal, 15 to 30 per cent; slack and pea, 15 to 40 per cent. In most of the mines a much better showing could be made if greater care were exercised in mining, but the introduction of large numbers of careless foreign workmen who are paid by the ton of run-of-mine coal makes it difficult to increase the percentage of lump coal. In the early days, when the miners were all Americans, the percentage of lump coal is said to have been greater.

The sulphur content of the coal is low, as shown in the table of analyses. In unweathered coal the sulphur forms iron sulphides that make thin yellow leaf-like plates and spots on the joints and, rarely, in the bedding planes. Pyritiferous concretions are almost unknown in this field. Within 50 feet of the surface the coal is veined with white stringers of gypsum and of iron sulphates derived from the weathering of the coal and the interaction of the sulphate solutions with calcium in the ground water.

Another feature of the weathering of the coal beds is their marked thinning out near the surface. Many coal beds that appear nearly fresh to the eye, except that the coal does not have its true luster, are reduced over 20 per cent in thickness by weathering. This is shown at a score or more of prospects, in which the coal does not have its full thickness within 10 to 25 feet of the surface. In the open cut on the Chandler bed in Alkali Gap a bed of coal which measured 6 feet, including partings, at a depth of 18 feet wedged out gradually to an 18-inch bed of coaly smut at the surface. At a depth of 6 feet, where to the eye the coal appeared but slightly weathered, its thickness was only 2 feet 6 inches. Prospecting in this field is not satisfactory unless carried to a depth of 15 feet or more, and surface measurements of coal beds on the outcrop are unreliable.

ECONOMIC CONDITIONS.

The larger mines are reached by spurs of the Denver and Rio Grande and the Atchison, Topeka and Santa Fe railroads. The principal markets for the coal are in California, Kansas, Nebraska, Oklahoma, and Texas. Denver and other Colorado cities consume a minor part of the production. In July, 1908, the lump coal of one mine in the northern part of the field was being sold for $3.25 a ton f. o. b., and equally good lump coal of another mine was sold for $2.75 a ton f. o. b. The slack and pea coal are sold together at 50 to 90 cents a ton at the mines, depending on the amount of ash and on local freight rates. Most of this fine coal is used in factories and power plants in the adjacent territory.

The laborers employed in the mines are largely foreigners, among whom Italians are the most numerous. For piecework the miners receive the usual prices paid in this section of the Rocky Mountains, 45 to 85 cents a ton, depending on the difficulty of mining, the use of machines, etc. The workmen are not well organized, and there has been only one strike, about six years ago, when labor troubles caused many of the mines to close. As already stated, the mine managers report that the introduction of large numbers of foreign workmen has diminished the percentage of lump coal in the product, and in one mine it is proposed to pay the miners a premium based on the percentage of lump coal they produce.

The coal land in this field has all passed from the control of the Government to private and corporate ownership. In recent realty transfers the prices have ranged from $40 to $200 an acre, the higher price having been paid for excellent land tributary to a developed mine.

SUMMARY.

The Canon City coal field is a small syncline of the Laramie formation, located in south-central Colorado, at the foot of Wet Mountain, which is the eastern range of the Rocky Mountain system in this region. The eastern limb of this syncline dips westward at angles of 2° to 5°, except at the northern margin, where the dips are 5° to 15° S. This limb is broad in comparison with the western limb, being 2 to 4 miles wide and about 12 miles long. It contains all the larger mines of the field, eight in number, that ship by rail. The western limb of the syncline is a narrow belt of nearly vertical or overturned strata, not more than 1,000 feet wide. The mines on this limb are small, only two of them having railroad connections, but the Nonac mine, located at the northwest corner of the field, in the axis of the syncline, formerly produced about 300 tons a day.

The coal is a high-grade domestic fuel. It is bituminous, noncoking, and comparatively clean to handle. Its calorific value ranges from 11,000 to 12,000 British thermal units, the lower values characterizing the coal of the southern part of the field; all of that of the northern part exceeds 11,600 British thermal units. The keeping quality of the coal is excellent.

THE TRINIDAD COAL FIELD, COLORADO.

By G. B. Richardson.

INTRODUCTION.

LOCATION.

The Trinidad field is part of a large coal-bearing area, known as the Raton Mountain or, preferably, the Raton Mesa coal region, that lies along the eastern base of the Front Range in Colorado and New Mexico. The state boundary line divides this area into two approximately equal parts, the New Mexico portion being known as the Raton field and the Colorado portion as the Trinidad field. Although topographically, geologically, and economically the region as a whole is a unit, for descriptive and statistical purposes the twofold division based on political boundaries is convenient and has long been in use. The Raton Mesa region is one of several disconnected coal-bearing areas along the eastern front of the Rocky Mountains in Colorado, including the Denver, Colorado Springs, and Canon City fields. The coal in all these fields occurs in the "Laramie" formation, which formerly occupied a much greater region than at present; probably all the fields were once continuous, but as a result of structural disturbance and erosion they have been separated into the present detached areas.

PREVIOUS WORK.

The first systematic study of the geology of the Trinidad coal field was made by F. M. Endlich,[a] of the Hayden Survey, in 1875.

John J. Stevenson,[b] in connection with the work of the Wheeler Survey, reexamined a portion of the area in 1878–79.

Ten years later Arthur Lakes[c] published an account of this region in a report of the Colorado School of Mines.

In 1893 R. C. Hills included an account of the Trinidad field in his paper on the coal fields of Colorado,[d] and this was followed by the admirable series of reports, the El Moro, Walsenburg, and Spanish Peaks folios of the Geologic Atlas of the United States, by the same author.

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[a] Ninth Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1877, pp. 192-206.

[b] Rept. U. S. Geog. Surveys W. 100th Mer., vol. 3, Supplement, 1881, pp. 102-225.

[c] Trinidad or Raton coal fields: Ann. Rept. Colorado School of Mines, 1889, pp. 87-112.

[d] Mineral Resources U. S. for 1892, U. S. Geol. Survey, 1893, pp. 324-331.

In 1902 L. S. Storrs[a] briefly reviewed the results of Hills's work in the Trinidad field.

A number of shorter papers relating to the Trinidad field, chiefly technologic, are listed below:

HOSEA, R. M. Coal washing, a description of the Colorado Fuel and Iron Company's washery at Sopris, Colo. Mines and Minerals, vol. 17, 1897, pp. 478, 479, 521–524.

——— The Primero mines. Mines and Minerals, vol. 24, 1904, pp. 521–526.

——— Tercio and Cuatro mines. Mines and Minerals, vol. 25, 1904, pp. 218–223.

——— Segundo coke plant. Mines and Minerals, vol. 25, 1905, pp. 4–10.

LAKES, ARTHUR. Coal fields of Colorado. Mines and Minerals, vol. 19, 1899, pp. 541–543.

——— Aguilar coal and oil district. Mines and Minerals, vol. 23, 1903, pp. 196–198.

——— The Occidental and other coal mines of Huerfano County, Colo. Mines and Minerals, vol. 25, 1905, pp. 473–474.

——— Coals of the southern Colorado or Walsenburg and Trinidad region. Mining Report, vol. 51, 1905, pp. 234-255.

MEADE, FRANK. Coal mines of Pictou, Colo. Mines and Minerals, vol. 21, 1900, pp. 1-3.

MCLAUGHLIN, J. E. Barella Mesa coal field. Mines and Minerals, vol. 24, 1904, p. 139.

WHITESIDE, F. W. The Delágua mines. Mines and Minerals, vol. 29, 1909, pp. 317–319.

Valuable data are also contained in the biennial reports of the state mine inspector.

PRESENT WORK.

Considering that the Trinidad field is so well known, another, which is not a final report, might seem superfluous. There has been, however, an increasing demand for information concerning this field, in connection with the sale of public lands, and because in the previous work no attempt was made to locate the coal outcrops with reference to land subdivisions there has been no satisfactory basis for the classification of the area. A reexamination of the field therefore became necessary, and a party consisting of J. H. Gardner, D. E. Winchester, O. J. Bowman, J. B. Mertie, and the writer spent three months of the season of 1908 in the field, the primary object being to collect data on which to base the classification and valuation of the public coal lands. The work consisted chiefly in locating the outcrop of the principal coal beds with reference to government corners, measuring the thickness of coal beds, and obtaining samples of coal for analysis. In addition fossils were collected, and such attention as was possible under the conditions of the work was devoted to the general geology of the region.

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[a] The Rocky Mountain coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902.

The location of the coal outcrops shown on the map (Pl. XX) was determined by plane-table stadia traverse, on a field scale of 2 inches to the mile, based on the few government corners which were found in the vicinity of the coal outcrops, and which are believed to be authentic. These are shown on the map by small circles. In some areas official resurveys must be made before the correct location of the coal outcrop can be established: There has been much contention over the location of government corners in this field, especially contiguous to the coal outcrop, and the condition of the land surveys is notoriously poor. It appears that in parts of the area corners were never officially established, and it is well known that some original monuments have been removed and that some corners have been illegally set. The network of sections and townships shown on the map is constructed according to data of the General Land Office and indicates a regularity throughout the field which probably does not exist.

A final report on this field must be postponed until the area is adequately surveyed, until the perplexing question of the age and correlation of the coal-bearing rocks is determined (which in turn must await more complete general knowledge of late Cretaceous and early Eocene paleobotany), and until the interior of the basin has been exploited with the drill.

ACKNOWLEDGMENTS.

The writer gratefully acknowledges the cordial cooperation in the prosecution of his work of the officials of practically all the mining companies in the Trinidad field. A considerable mass of information, consisting of mine maps, diamond-drill records, etc., was placed at his disposal for study, but for business considerations much of this information has been withheld from publication. Thanks are especially due to Messrs. R. C. Hills, of the Victor Fuel Company; E. H. Wietzel, of the Colorado Fuel and Iron Company; J. D. Skinner, of the Northern Coal and Coke Company; F. Guiterman, of the Carbon Coal and Coke Company; and E. E. Shumway, of the Rocky Mountain Fuel Company.

RELIEF AND DRAINAGE.

The Raton Mesa coal region occupies a hilly country east of the Rocky Mountains at the border of the Great Plains and Cordilleran provinces. In the Colorado portion of the region—the Trinidad coal field—the surface elevations of the greater part of the area range from about 6,000 feet along the eastern margin to more than 9,000 feet above sea level at the west end of the field. Near the western border the Spanish Peaks, two conical mountains composed of igneous rocks which rise abruptly above the surrounding area and culminate in an elevation of 13,623 feet, are the dominating feature of the topography. At the southeast end of the field the lava-capped Raton Mesa, consisting of a number of dissected table-lands, rises to an altitude of about 11,000 feet. Fishers Peak, an outlying remnant of the mesa, is the most conspicuous landmark in the immediate vicinity of Trinidad.

The main portion of the Trinidad coal field occupies a dissected upland area which is the northern continuation of the Raton Hills of New Mexico. East of the coal field a desert plain stretches as far as the eye can see, and immediately west of the field is the lofty Sangre de Cristo Range, the Front Range of the Rocky Mountain system in this latitude. On the north the surface gradually slopes down to the lowland at the base of Wet Mountain.

The topography of the coal field is directly related to the character and structure of the underlying rocks, which, as described below, consist generally of almost flat-lying beds of sandstone and shale and local masses of igneous rocks, including stocks, dikes, sills, and lava flows. The conspicuous highlands are formed of hard igneous rocks from which the associated softer strata have been eroded. The surface of the larger part of the area is composed of a series of disconnected flat-topped benches or stratum planes that rise in altitude steplike toward the west. The eroded ends of the benches form cliffs which are composed of the outcropping edges of beds of hard sandstone. The benches are underlain and upheld by sandstone from which the softer beds that now form the slopes of the next higher benches have been eroded.

Along the eastern and western margins of the field, where the inclination of the rocks is greater than in the interior, dip slopes are developed on the harder beds and an interrupted line of sandstone cliffs separates the coal field from the surrounding lowland areas that are underlain by shale. East of the coal field the lowland extends for many miles as an almost unbroken plain; but on the west, where the dip of the rocks is much steeper, the shale outcrops in a narrow belt of lowland, west of which beds of underlying sandstone form hogbacks at the base of the Sangre de Cristo Range. The most conspicuous line of hogbacks, locally known as the Stonewall, is composed of Dakota sandstone standing almost perpendicularly and extending parallel to and a few miles west of the coal field throughout its length.

The drainage of the Colorado portion of the Raton Mesa coal region is tributary to Arkansas River and that of the New Mexico portion to Canadian River, the divide being not far from and generally south of the state boundary line. The chief streams in the Colorado field are Purgatory and Cuchara rivers, which rise in the Sangre de Cristo Range and flow northeastward across the field independently of the local structure. A small portion of the extreme north end of the

Trinidad field drains into Huerfano River. A number of smaller streams radiate northward and southward from the Spanish Peaks, most of which are tributary either to the Purgatory or to the Cuchara. Apishapa River, the main stream that rises in the Spanish Peaks, flows northeastward directly into Arkansas River. The cliffs along the eastern margin of the coal field are drained through a number of short canyons. Only Purgatory and Cuchara rivers flow perennially, and the discharge of these is small, especially in the eastern portion of the field; the others, except during floods, are dry for the greater part of the year.

The valleys of the larger streams are fringed with well-developed terraces, which descend in altitude with approximately the grade of the streams and merge into broad débris-covered benches along the base of the cliffs at the eastern margin of the field. The river terraces are capped with a cover of sand and gravel ranging from 5 to 20 feet in thickness, resting on bed rock which outcrops in the sides of the valleys above the flood plains. The marginal benches are particularly conspicuous in the vicinity of Trinidad, where they are well developed at three distinct levels.

ACCESSIBILITY.

The Trinidad coal field is easily accessible and is reached by several important railroads. The Atchison, Topeka and Santa Fe Railway enters the field at Trinidad and passes up North Raton Creek on its way over Raton Pass. The shale lowland at the eastern base of the coal field is traversed by the Colorado and Southern and the Denver and Rio Grande railroads, each of which taps the coal field by several branch lines. The Denver and Rio Grande crosses the west end of the area between Walsenburg and La Veta, and a branch of that road extends around the northern coal outcrop between Walsenburg and Tioga. The Colorado and Wyoming Railroad, controlled by the Colorado Fuel and Iron Company, was built up Purgatory Valley between Trinidad and Tercio for the express purpose of developing the coal field. Any part of the Trinidad coal field can be reached by rail, although locally in the western part relatively steep grades will be encountered.

DESCRIPTIVE GEOLOGY.

GENERAL STATEMENT.

The rocks of the Trinidad coal field form an unsymmetrical syncline which is one of several basins that extend along the eastern front of the Rocky Mountains. The strata along the western limb of the fold dip steeply eastward, those along the eastern limb dip gently westward, and in the center of the basin the strata lie almost flat.

The coal-bearing rocks, as in all the fields throughout the Colorado portion of the Rocky Mountain region, are of Upper Cretaceous age and in the Trinidad field are members of the "Laramie" formation. These rocks are overlain by early Tertiary beds and underlain by a great mass of Cretaceous and older strata. Rocks of early Mesozoic and Paleozoic age outcrop on the Sangre de Cristo Range and underlie the coal field to a depth of many thousand feet. The Trinidad field has been the seat of profound igneous activity, the evidences of which are found in the great intrusive bodies which form the Spanish Peaks, in the marvelous system of dikes which radiate from this eruptive center, and in the lava-capped Raton Mesa.

STRATIGRAPHY.

GENERAL SECTION.

The following table summarizes the sedimentary rocks associated with the coal measures of the Trinidad field, the formation names being those used by R. C. Hills.

Geologic formations in Trinidad coal field.

System.	Series.	Group.	Formation.	Thickness (feet).	Description and occurrence.
Tertiary.	Eocene.		Huerfano.	1,500+	Coarse and fine grained red feldspathic sandstone on the flanks of West Spanish Peaks.
			Unconformity		
		Shoshone.	Poison Canyon and Cuchara.	2,000±	Massive beds of usually coarse-textured feldspathic sandstone; lower beds of conglomerate; subordinate interbedded drab shale. Outcrop in central highland area of coal field and on flanks of Spanish Peaks.
			Unconformity		
Cretaceous.	Upper Cretaceous.		"Laramie."	1,000 to 3,000.	Alternating beds of fine-textured buff feldspathic sandstone and drab sandy and clay shale containing workable beds of coal in the lower part. A variant bed of conglomerate occurring locally about 200 feet above the base of the formation occupies the greater part of the surface of the Trinidad coal field and underlies the entire area.
		Montana.	Trinidad sandstone.	150 to 225.	Massive fine-grained feldspathic sandstone lying between thinner-bedded sandstone and shale by which it merges into the overlying and underlying formations. Outcrops in conspicuous cliffs at the base of the coal measures.
			Pierre shale.	1,000+	Drab clay shale containing lenses of impure limestone. The Pierre shale underlies the coal basin and outcrops in a lowland belt east, north, and west of the Trinidad field.

UPPER CRETACEOUS.

PIERRE SHALE.

The Pierre shale has a wide distribution in the Great Plains region and outcrops in many disconnected areas along the base of the front ranges of the Rocky Mountains. In the Trinidad coal field it underlies the syncline of coal-bearing rocks outcropping along the eastern, northern, and western margins of the basin. On the west, where the dip of the rocks is steep, the shale occupies a narrow lowland belt at the base of the Sangre de Cristo Range; on the north, in the vicinity of Huerfano River, where the dips flatten out and the axis of the syncline rises, the shale outcrop occupies a wider zone; and along the eastern margin of the basin, where the strata lie almost flat, the Pierre underlies the broad plain that extends far to the east of the coal-measure cliffs.

In the area under consideration the Pierre is a mass of homogeneous drab clay shale more than 1,000 feet thick, the monotony of which is varied only by the presence of local thin lenses of limestone. The shale is underalin by a number of other Cretaceous and older formations, which need not be considered here, and it merges into the overlying Trinidad sandstone. The transition to the overlying rocks is gradual and is marked by a change from shale to sandstone through intermediate beds of sandy shale and thin-bedded sandstone. (See fig. 4.)

The following fossils, determined by T. W. Stanton, were collected in 1908 from the upper part of the Pierre shale at different localities in the Trinidad field: *Inoceramus sagensis* Owen, *I. cripsi* var. *barabini* Morton, *I. vanuxemi* M. and H.? *Baculites ovatus* Say, *B. compressus* Say, *Ostrea* sp.

The following forms were collected by T. W. Stanton and the writer in the shale 1¾ miles east of Monson, on the Colorado and Southern Railway, about 1,000 feet below the Trinidad sandstone: *Ostrea pellucida* M. and H., *Inoceramus vanuxemi* M. and H.?, *Cucullæa* sp., *Lucina* sp., *Volutoderma* sp., *Scaphites nodosus* Owen var. Doctor Stanton reports that these fossils indicate the Pierre shale of the Arkansas Valley and the Denver Basin.

TRINIDAD SANDSTONE.

The Trinidad sandstone is a relatively thin but important formation that lies between the Pierre shale and the coal-bearing rocks. It is remarkably persistent and outcrops around the margin of the basin in conspicuous ledges. Its importance is due to the fact that it almost immediately underlies the principal group of coal beds and, being readily recognizable, is a valuable aid in prospecting. The outcrop is particularly conspicuous along the eastern margin of the field and is typically developed in the vicinity of Trinidad, where the sandstone forms a prominent bench about 200 feet high, below which are slopes of Pierre shale. This bench, locally dissected by streams, is the most conspicuous topographic feature of the eastern margin of the coal field between Trinidad and Walsenburg. Along the western margin of the field the Trinidad sandstone is much less prominent, though it is locally well exposed, and at the north end, where the topography is more subdued than farther south, the formation is inconspicuous.

The Trinidad sandstone, as defined by Hills, consists of a lower zone of thin-bedded, fine-grained gray sandstone, the layers of which are separated from one another by thinner partings of shale, and an upper zone of massive light-gray sandstone which in places is capped by a few feet of brown sandstone in contact with the overlying coal measures. Locally a threefold division of the Trinidad sandstone is developed, a middle massive sandstone member, usually light colored, about 75 feet thick, lying between thinner-bedded sandstones and shales. The formation ranges from 150 to 225 feet in thickness. The sandstones are all fine textured and are composed of grains of quartz and feldspar in about equal proportions with a subordinate amount of mica, usually muscovite. In the upper beds of the formation there are well-developed ripple marks, worm tracks, and other indications of shallow-water conditions. The Trinidad sandstone is succeeded, apparently conformably, by carbonaceous shale and coal-bearing rocks and, as already stated, it grades downward into the Pierre shale. The formation is an off-shore deposit marking the transition from deep-sea to littoral conditions of deposition.

The lower portion of the sandstone contains marine shells of which the following collection, obtained by T. W. Stanton and the writer in the railroad cut east of the Pryor mine, near Monson station, is typical: *Ostrea* sp., *Ostrea pellucida* M. and H., *Chlamys nebrascensis* M. and H., *Avicula nebrascana* E. and S., *Inoceramus cripsi* var. *barabini* Morton.

This fauna is considered to be upper Montana by Doctor Stanton, who reports that although the last two species of the list range through a large part of the Montana group, the other two identified forms are known only from the upper Pierre and Fox Hills. The massive sandstone member of the formation is characterized by abundant remains of a seaweed which in the area under consideration is practically limited to the Trinidad sandstone. This fossil, *Halymenites major* Lesquereux, is pitted and cylindrical in cross section and is easily recognized.

"LARAMIE" FORMATION.

The Trinidad sandstone is conformably overlain by a mass of coal-bearing sandstone and shale which ranges in thickness from 3,000 feet at the west end of the field to 1,500 feet at the east end. The greater part of the surface of the coal field is occupied by these rocks, which outcrop in the area between the Trinidad sandstone escarpment and the highland surrounding the Spanish Peaks.

The sandstones are both thick and thin bedded, occurring locally in massive beds up to 50 feet thick but usually in layers ranging from 2 to 10 feet. They are fine textured and of a general buff tone but are in places gray, brownish, or almost white. Their composition is characteristically feldspathic and they consist of grains of quartz and feldspar in about equal proportions with occasional flakes of white mica. The shale is usually of a drab or grayish color but contiguous to coal beds is in many places black. The beds range from a fine clay shale to those with varying admixtures of sand grading into sandy shales or shaly sandstones. The succession of the strata is extremely varied. No two sections are exactly alike and it is of common occurrence for a bed of massive sandstone to merge both vertically and horizontally into beds of thin sandstone or shale.

The occurrence of coal in the lower part of the formation is described at length below. No one bed has been found to persist for any great distance, but on the other hand the lowest group of coal beds, consisting of lenses of coal of workable thickness occurring in the lower 250 feet of the formation, is remarkably persistent and has been traced throughout the field. More varied upper beds of coal occur at different horizons up to about 1,200 feet above the top of the Trinidad sandstone, but above this horizon no coal has been found.

About 200 feet above the top of the Trinidad sandstone there occurs at various localities, but not throughout the field, a bed of conglomeratic sandstone which locally becomes a true conglomerate. The pebbles are composed of rounded bits of quartz which vary from a fraction of an inch up to 2 inches in diameter. The conglomerate is thicker and the pebbles are larger along the western margin of the field than in the eastern part. In the vicinity of Tercio, for instance, the conglomerate is 150 feet thick, whereas in the eastern part of the field not more than 20 feet of it has been observed and locally it fades away and disappears. In the vicinity of Trinidad and in other places no corresponding conglomerate has been found. (See fig. 4 and Pl. XIX.) It is noteworthy that the pebbles of this conglomerate in the Trinidad field so far as observed consist entirely of quartz, which is in marked contrast to the varied composition of the pebbles in the conglomerate at the base of the Poison Canyon formation.

The significance of the conglomerate in the Trinidad field remains to be determined. Occurring intermittently in the midst of coal-bearing rocks it may represent only a local change in conditions of deposition, or, as maintained by Lee,[a] for a conglomerate in the Raton field, presumably the same as the one just described, it may mark an unconformity contemporaneous with the post-Laramie unconformity of the Denver Basin. In the Trinidad coal field the post-Laramie uplift has been considered to be marked by the basal conglomerate of the Poison Canyon formation described below. The final word concerning the age of the rocks above and below this conglomerate in the coal measures, involving its significance as a hiatus marker, must come from the paleontologist. Fossil shells occur very rarely if at all in these rocks, and the burden of proof falls on paleobotany. Fossil leaves are abundant and considerable numbers were collected in 1908 with the hope of settling the problem.

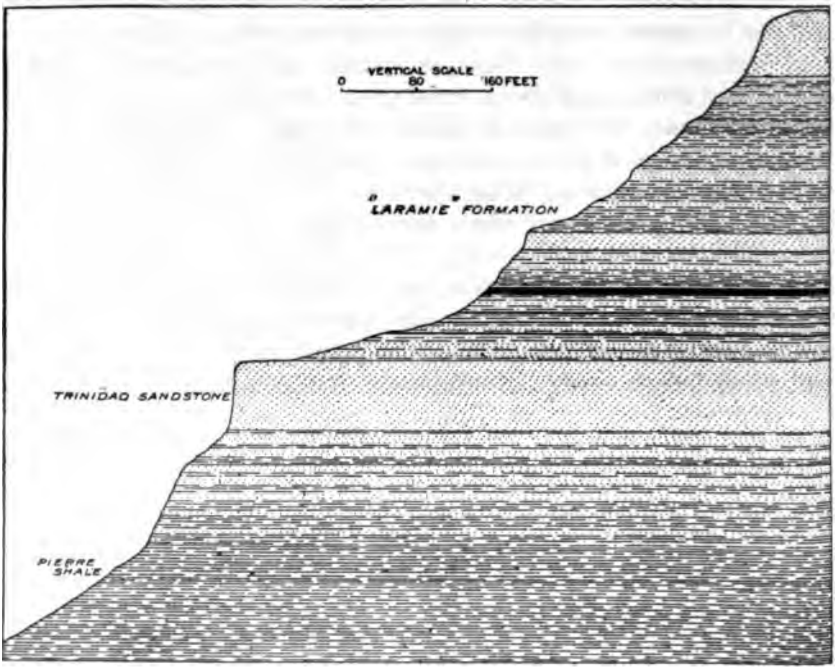

FIGURE 4.—Section of cliffs 4 miles north of Trinidad, Colo., showing transition from Pierre shale to Trinidad sandstone and lower part of "Laramie" formation.

In all 62 species of fossil leaves from the coal-bearing rocks of the Trinidad field have been identified by F. H. Knowlton, but of this number 20 are known only from the Raton Mesa region and therefore are of no value in correlation, and of the remaining 42 species 15 are known to have a wide range, occurring from the Montana to the Eocene. Only 12 species are also found in the Laramie of the Denver region. These figures are tentative, and until further paleobotanic knowledge is available the age of these rocks must remain unsettled. For the present it seems best to retain the old nomenclature and to refer the strata occurring between the Trinidad sandstone and the Poison Canyon formation to the Laramie.

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[a] Lee, W. T., Bull. Geol. Soc. America, vol. 20, 1909, pp. 357-368.

EOCENE.

SHOSHONE GROUP (POISON CANYON AND CUCHARA FORMATIONS).

The "Laramie" formation in the Trinidad coal field is unconformably overlain by a group of rocks about 2,000 feet thick, consisting of conglomerate, sandstone, and shale, which R. C. Hills separated into the Poison Canyon and Cuchara formations, but which for present purposes may be considered together. These rocks, which commonly outcrop in conspicuous ledges, occupy the upland area at the base of the Spanish Peaks, approximately above the 7,500-foot contour.

On the western margin of the coal basin contiguous to the source of the material (the Sangre de Cristo Range) the lowest Eocene strata are composed of conspicuous beds of conglomerate and intervening beds of coarse sandstone. The conglomerate is made up of rounded pebbles and bowlders up to 3 feet in diameter, consisting of granite, gneiss, quartzite, and a variety of porphyritic igneous rocks. The pebbles decrease in size and abundance toward the eastern part of the field. Scattered pebbles of granite and quartzite, however, occur in coarse-grained sandstones along the eastern contact, although in that part of the field in general it is difficult to draw a sharp line of demarcation between the Eocene and the underlying "Laramie." In the northern part of the field, however, there is a distinct overlap of the younger rocks upon the older, which completely conceals the probable continuation of the coal field toward Huerfano Peak.

The sandstones are generally buff in color, but locally are gray and in places weather to a slight pinkish tinge. They are composed of grains of quartz, feldspar, and mica. The finer-textured varieties closely resemble the underlying sandstones of the "Laramie" formation but the presence of local pebbles of granite, quartzite, etc., generally serves to distinguish them. The shale, which is yellow to drab in color and variously composed of clay and sand, is of subordinate occurrence and probably constitutes only about a third of the group.

Hills found no fossils in these beds, but because of their stratigraphic position considered that they were probably equivalent to the post-Laramie deposits of the Denver Basin. In 1908 several collections of leaves were obtained from sandstones near the base of this group of rocks, which Knowlton states are of Denver age, thus confirming Hills's conjecture.

The name Shoshone group [a] has recently been proposed to include those rocks which unconformably succeed the "Laramie" and which are overlain by the Fort Union or Wasatch beds where they are present. The Poison Canyon and Cuchara formations therefore belong to the Shoshone group.

HUERFANO FORMATION.

The somber, buff-colored beds which have just been described are overlain, presumably with unconformity, by a mass of red beds at least 1,200 feet thick, which Hills has named the Huerfano formation. The type locality is in Huerfano Park,[b] only a few miles northwest of the north end of the Trinidad coal field, the probable former connection of the beds in the two areas having been severed by erosion. In the Trinidad coal field the Huerfano formation occurs only on the flanks of West Spanish Peak, where at least 1,200 feet of red beds are exposed. The beds consist of coarse red feldspathic sandstone and red sandy shale which locally are mottled with green specks.

No fossils have been found in these rocks adjacent to Spanish Peaks, but their occurrence and physical appearance leave little room for doubt that they are part of the Huerfano formation, which is so well developed in Huerfano Park. In the Huerfano Park beds Hills, Osborn, and Wortman have collected a number of fossil bones, from which Osborn concludes[c] that the "formation began during the Wind River and continued without a break into the period of the lower Bridger."

In connection with the survey of the Trinidad coal field a reconnaissance was made in Huerfano Park and a few fossil bones were collected, among which J. W. Gidley, of the United States National Museum, reports the presence of *Crocodilus* sp. ?, *Baptemys* sp. ?, *Coryphodon* sp., and *Oxyæna morsitans* ?, and states that the two last-named genera, so far as known, have been found only in the Wasatch. To judge from this statement, and from the fact that the Wasatch formation where well developed west of the Rocky Mountains is characteristically red, it appears that the Huerfano formation may also be in part Wasatch.

IGNEOUS ROCKS.

Igneous rocks occur abundantly in the Trinidad coal field and are of importance, not only in connection with the general geology of the region, but because they have a direct economic bearing on the value of the coals.

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[a] Cross, Whitman, Proc. Washington Acad. Sci., vol. 11, 1909, pp. 27-45.

[b] Hills, R. C., Recently discovered Tertiary beds of the Huerfano River basin, Colorado: Proc. Colorado Sci. Soc., vol. 3. 1889, pp. 217-223.

[c] Osborn, H. F., Cenozoic mammal horizons of western North America: Bull. U. S. Geol. Survey No. 361, 1909, p. 48.

The Trinidad field has been the seat of great igneous activity at different times since the deposition of the Huerfano formation in the early part of the Eocene period. Masses of igneous rock of various composition have been intruded into the strata, and flows of lava have been poured out on the surface, resulting in very complex igneous phenomena.

The intrusion of the great stocks that form the core of the Spanish Peaks must have destroyed a considerable volume of coal with which the molten rock came into contact, and the effect of the heat probably exerted a considerable metamorphosing influence on a still larger mass. But because of the great depth beneath the surface of the principal coal beds in the vicinity of the peaks such effects probably are of little practical importance. In connection with the intrusion of the main Spanish Peaks stocks there was developed a system of dikes, which, centering in the peaks, radiate for several miles from them in all directions;[a] and a great system of sills also originated in the main centers of eruption. The dikes are more or less vertical masses of igneous rock only a few feet thick which have cut across the strata, and are of great length compared with their thickness. Where a dike has come into contact with a bed of coal the coal has been metamorphosed by the heat of the molten igneous rock into natural coke. But as a general rule the metamorphism has not proceeded much farther into the coal bed than a distance on each

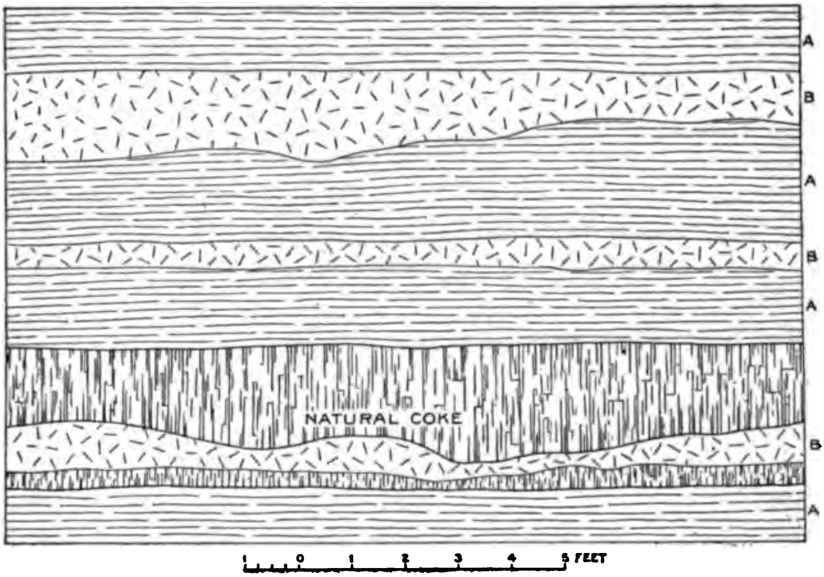

FIGURE 5.—Sills of igneous rock in "Laramie" formation and bed of natural coke, in Purgatory Valley, opposite Sopris Plaza, near Trinidad, Colo. A, Shale; B, sill of igneous rock.

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[a] See folios 68 and 71, Geol. Atlas U. S.

side of the dike about equal to its own thickness. Dikes have been encountered in a number of mines, and though they are hard to cut through they present few other practical difficulties. On the other hand, the sills, which are more or less nearly horizontal masses of igneous rock, usually only a foot or so thick but of enormous width compared with their thickness, have been intruded along the bedding planes and between the strata instead of cutting across the beds like dikes. Consequently, wherever a sill has been intruded along a bed of coal the latter has been converted to natural coke over a large area. (See fig. 5.)

The location of the principal dikes and sills in the Trinidad coal field is shown in the maps of the Spanish Peaks and Walsenburg folios, but of course the existence of sills that do not outcrop can be determined only by drilling or actual mine work.

The great lava flows on Raton Mesa are far above the coals and appear to have had practically no effect on them. But possibly some of the lava flows are directly connected with conduits beneath them, and if so the coal in the immediate vicinity of the intrusive rocks has doubtless been metamorphosed. Intrusive masses in the Raton Mesa will probably be discovered in the progress of mining.

STRUCTURE.

The rocks of the Trinidad coal field form an unsymmetrical fold, named the Spanish Peaks syncline, the axial trend of which is northwest-southeast. At the north this fold merges into the Huerfano Park syncline and at the south, in the Raton field, New Mexico, according to Lee, the dips become less and the strata finally lie practically flat. The Spanish Peaks syncline is characterized by steep eastward dips, ranging from 20° to 90° on the western limb, and by low westward dips, ranging from 2° to 10°, on the eastern limb; while in a relatively broad area in the interior of the field the strata lie almost flat.

This comparatively simple structure is modified by local complications. Along the western margin the strike of the Dakota sandstone, which stands almost vertically and outcrops in the prominent hogback called the Stonewall, is distinctly curved. Between the Colorado-New Mexico boundary and Cuchara River the strike of the sandstone is northeastward, then northwestward, and again northeastward, the trend resembling a rude S-like curve. Conforming with this structure, the adjacent coal measures are similarly warped, as shown by the position of the coal outcrop. In a relatively narrow zone east of the Dakota hogback the western limb of the Spanish Peaks syncline is modified by local folds. At the southwestern margin of the basin, in the vicinity of Tercio, and at the northwestern margin, in the vicinity of La Veta, subsidiary anticlines and synclines are developed. (See pp. 418 and 422.)

At the north end of the coal field the Wet Mountain uplift has so warped the strata that the rocks northwest of Walsenberg form a southward-plunging syncline, and farther northwest, at the south end of Huerfano Park, the strata swing around so as to conform to the normal southwesterly dips of the main basin.

In the vicinity of Morley, in the southern part of the field, a disturbance has domed the strata and brought up the Pierre shale and Trinidad sandstone in the midst of the basin. This fold is a narrow, elongated dome, the axis of which strikes northwest and southeast, and which, measured by the outcrop of the exposed Pierre shale, is about a mile long and half a mile wide. The strata dip away on all sides from the center at angles averaging about 10°. Other structural irregularities are noted below.

In the valley of Guajatoyan Creek, above the mouth of Coal Creek, in the western part of the field, where the strata for the most part dip eastward, there is a belt of westward-dipping rocks which is probably caused by faulting.

Between Segundo and Sopris the impossibility of tracing the coal beds across Purgatory River suggests the presence of a fault.

About 5½ miles up Reilly Canyon from its mouth there is a bed of massive sandstone well exposed along the roadside lying almost flat on thin-bedded sandstone and shale that are tilted at an angle of about 20°. These conditions were observed only in this one locality. Cross-bedding may possibly account for these relations, but a local unconformity is strongly suggested. The horizon is about 600 feet above the Trinidad sandstone.

Northwest of Aguilar a local flexure of the strata causes abnormally steep dips in a narrow zone in which the Green Cañon mine is located.

In the vicinity of Santa Clara Creek, near the eastern margin of the field, a number of small normal faults are present, as described on page 413.

Details of structure are given below in connection with descriptions of the occurrence of the coal.

THE COAL.

PRELIMINARY NOTE.

In the description of the coal, the field is divided for convenience into the following divisions: Eastern outcrop, including the Trinidad and Walsenburg districts; western outcrop, including the La Veta, Stonewall, and Tercio districts; and interior of the field, including the Morley and Purgatory districts and undeveloped areas. In following the description it will be of assistance to refer to the diamond-drill sections, Plate XIX, and the map, Plate XX. The diamond-drill sections were plotted from records furnished by several mining companies. The sections show graphically the stratigraphy of the coal-bearing rocks and emphasize the variance in the occurrence of the coal beds. The holes are distributed along the eastern margin of the field, 26 being in Las Animas and 6 in Huerfano County, but at the request of the mining companies the locations of the holes are not given. The map, in addition to showing the location of the mines and the outcrop of the principal coal beds, also shows the approximate depth of the Trinidad sandstone beneath the surface. This information was obtained by combining structure contours drawn to the Trinidad sandstone with topographic contours. Although from the nature of the case the boundary lines separating the areas of different depth shown on Plate XX can not be exact, they are nevertheless in general believed to be close approximations. The most doubtful areas are in the interior of the field where little information is available.

EASTERN OUTCROP.

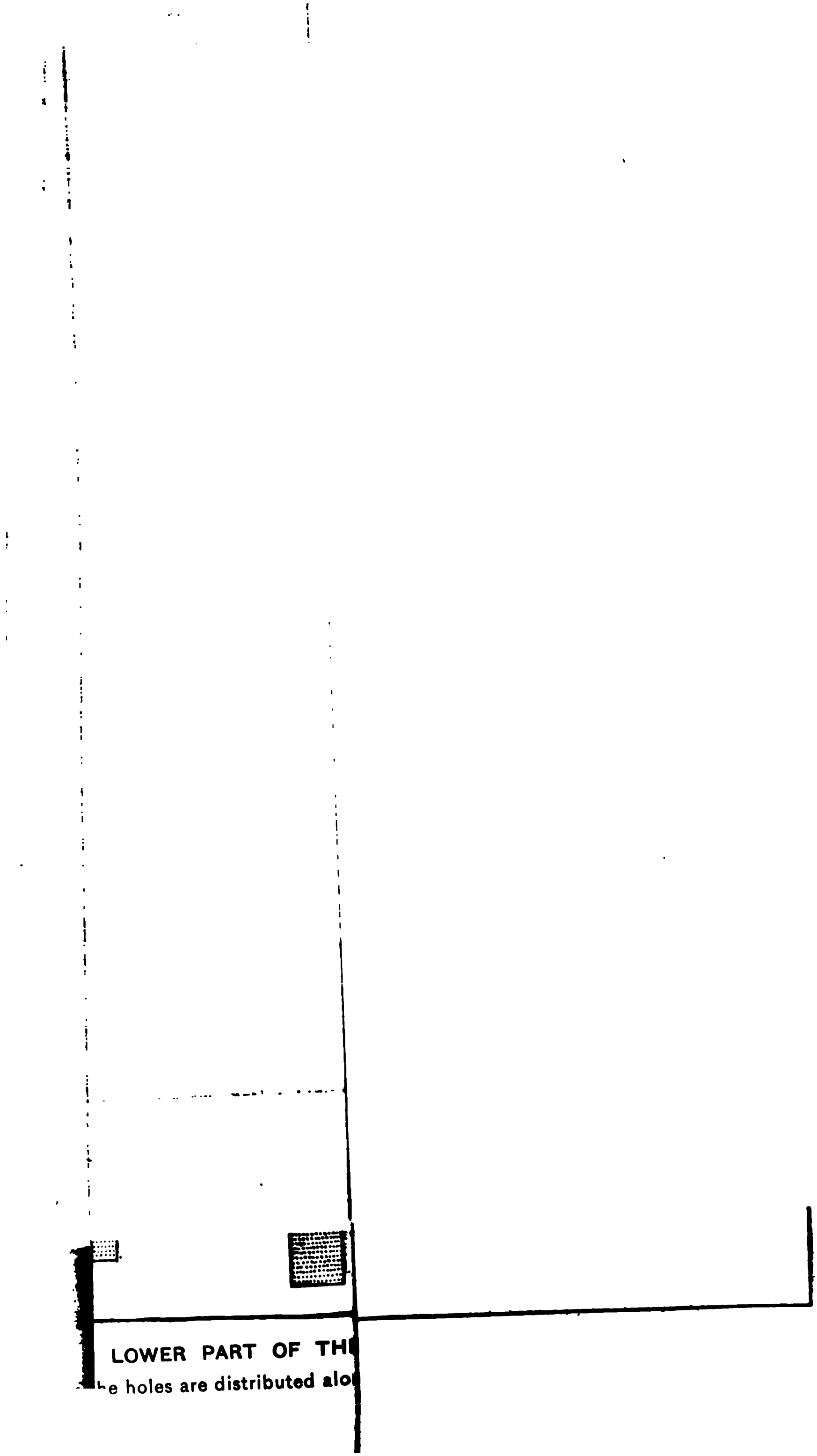
The eastern part of the Trinidad coal field is divided into the Trinidad and Walsenburg districts, named from the principal town in each. The difference in the character of the coal in the two districts makes the division a natural one, although the transition from a coking coal in the south to a noncoking coal in the north is too gradual to permit the drawing of a sharp division line between them; nevertheless, the boundary between Las Animas and Huerfano counties is generally considered as separating the districts.

TRINIDAD DISTRICT.

GENERAL CONDITIONS.

The Trinidad district includes the area contiguous to the outcrops of coal along the eastern margin of the field between the Colorado-New Mexico and the Las Animas-Huerfano County boundary lines.

For a distance of 15 miles northwest of the state boundary the "Laramie" outcrops in the steep slopes of Raton Mesa. The mesa is capped by flows of basaltic lava lying on the coal-bearing rocks, and the Pierre shale outcropping beneath cliffs of Trinidad sandstone underlies the plain at the base of the mesa. Erosion by Purgatory River and its tributaries has caused a deep embayment of the coal outcrops, which extend around the northern slopes of Raton Mesa, so that the lowest coal bed passes beneath the broad valley near Sopris, 4 miles southwest of Trinidad. Purgatory Valley is broad and open and is bounded by sandstone cliffs.



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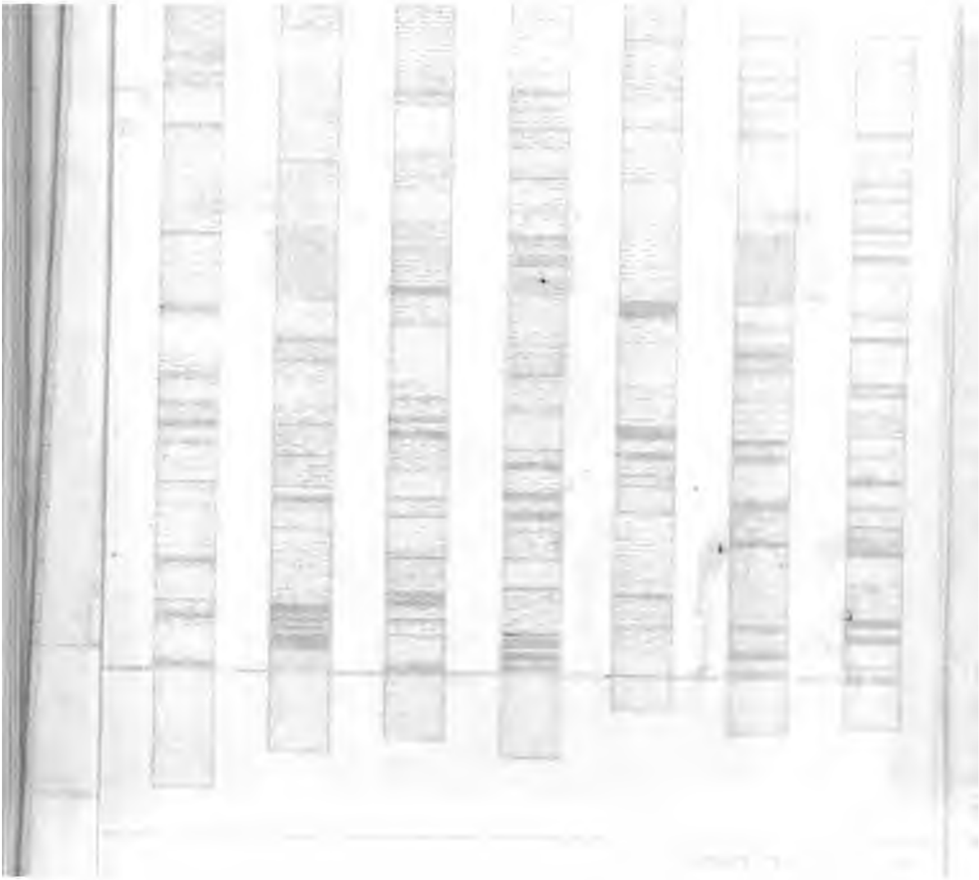

West and north of Trinidad the Trinidad sandstone forms a prominent bench bordered by an escarpment, below which are steep slopes of Pierre shale. The lowest group of coal beds outcrops in the slope immediately above and west of the Trinidad sandstone bench and can be readily located by the topography. Above the coal beds the country rises toward Spanish Peaks in a series of benches and intervening escarpments, the topography corresponding to the varying hardness of the underlying beds of sandstone and shale, which dip westward at a low angle. This area is much dissected by streams that head in Spanish Peaks and the outcrops of the coal beds are consequently intricately scalloped, extending up each valley and around the intervening divides.

The occurrence of coal in the Trinidad district will be described under three headings—the lower, middle, and upper groups.

LOWER COAL GROUP.

The lower group of coals is the most important and persistent in the entire field. It consists of one to eight workable coal beds which occur within a zone 250 feet thick above the top of the Trinidad sandstone. This coal group is present throughout the field, though in some places there are many more coal beds than in others and the beds are extremely varied in thickness. No bed has been traced for more than a few miles and it should not be assumed, without actual tracing, that a bed in one part of the district is necessarily the same as one occurring at the same distance above the Trinidad sandstone in another part of the district.

The following summary description of the occurrence and thickness of coal beds in the lower group in the Trinidad district begins at the south and proceeds in general northward.

Little is known of the coal in the extreme southeastern part of the Trinidad field between the state boundary and Gray Creek, although in the New Mexico area a number of mines are in operation and it is probable that Raton Mesa is underlain by a fine body of coal. In Colorado the thick accumulation of talus and the dense cover of vegetation along the northern slopes of the mesa has retarded prospecting and development. The Trinidad sandstone, however, outcrops in its usual conspicuous cliffs and can be readily traced. The broken line on the map shows the approximate location of the base of the coal-bearing rocks in this area. Between the New Mexico-Colorado boundary and San Francisco Creek, in T. 34 S., R. 62 W., this line was located by the party in charge of Willis T. Lee during his survey of the Raton coal field in 1908.

The southernmost locality along the eastern margin of the Trinidad field where coal has been developed is in the vicinity of Gray Creek, in the southeast corner of T. 33 S., R. 63 W., where the Gray Creek mine of the Victor Fuel Company (No. 4)[a] is located. Within a zone of 150 feet above the Trinidad sandstone in the vicinity of Gray Creek there are from two to six beds of coal more than 2 feet thick. A number of measurements show one good bed between 4 feet 2 inches and 5 feet 10 inches thick, and in a few sections a bed 13 feet 4 inches thick has been found. The coal worked in the Gray Creek mine is irregular in thickness, ranging between 4 and 14 feet. Partings of shale or sandstone in places separate the bed into several benches, but locally they disappear, leaving one thick bed of coal. Over much of the area worked in the Gray Creek mine there is a good sandstone roof, though in places the roof is shale. The floor is shale and locally causes trouble by heaving when the pillars are drawn. The coal bed lies almost flat and is worked from four drifts on the outcrop.

The Engle (No. 5) and Starkville (No. 10) mines of the Colorado Fuel and Iron Company are the oldest and largest in the Trinidad district. The workings of these two mines are connected, and together they cover an area of about 3½ square miles. The Engle mine is situated 3 miles northwest of Gray Creek and 2 miles southeast of Trinidad, on the northern slopes of Raton Mesa, below Fishers Peak, and is reached by a branch line of the Denver and Rio Grande Railroad. For a number of years coal from the Engle mine was coked in the ovens at Elmoro, 4 miles northeast of Trinidad. The mouth of the Starkville mine is situated on the main line of the Atchison, Topeka and Santa Fe Railway on the east side of North Raton Creek, 3 miles south of Trinidad.

The coal bed worked in the Engle and Starkville mines lies between 30 and 50 feet above the Trinidad sandstone and varies in thickness from 4 to 8 feet or more. At the entrance to the Engle mine the following section was measured:

Section of coal bed at entrance to Engle mine.

	Ft.	In.
Sandstone.		
Shale		8-12
Coal	4	
Shale, coaly		4
Coal	4	
Shale.		
Total coal	8	

It is reported that the average thickness of the bed in the Engle mine is between 6 and 7 feet, and that two partings of bony coal, each about 3 inches thick, usually separate the bed into three benches, although in places they disappear and leave a clean bed of coal. In some parts of the mine a bed of sandstone makes a good roof, but in other parts a "draw slate" appears between the sandstone and the coal, causing a poor roof. The floor is a sandy shale.

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[a] Numbers in parentheses refer to locations on Plate XX.

The following section was measured in room 6, entry G4, of the Starkville mine:

Section of coal bed in Starkville mine.

	Ft.	In.
Shale roof.		
Coal	3	2
Coal, bony		4
Coal		3
Coal, bony		2½
Coal	1	2
Coal, bony		2
Coal	1	11
Shale floor.		
Total coal	7	2½

The workings of the Engle and Starkville mines are being extended southward toward Fishers Peak. The deepest parts of the mines are now under a cover of approximately 1,100 feet, but owing to the rapid rise of the surface further extension of the workings toward Fishers Peak will carry them under a considerably greater thickness of cover.

Along the outcrop between the entrances to the Engle and Starkville mines there are three relatively small openings, known as the Newcomb, Bloom, and Abercrombie mines. At the Bloom mine (No. 7) of the Jeffreys Coal and Mining Company, the largest of the three, two beds are exposed about 90 feet apart, which measured as follows:

Section of coal beds at Bloom mine.

	Ft.	In.
Shale.		
Coal	1	6
Bone		8
Coal	5	
Shale.		
Interval	90	
Coal	3	2
Bone		5
Coal	1	3
Total coal	10	11

Coal from the Bloom mine is hauled in wagons to Trinidad.

The Engle-Starkville coal bed has not been traced far west of North Raton Creek, and a bed only a few feet above the Trinidad sandstone is worked at the Francisco (No. 12) and Piedmont (No. 13) mines of the Rocky Mountain Fuel Company. These are connected workings in sec. 34, T. 33 S., R. 64 W. In the Francisco mine the upper of two benches is worked and in the Piedmont the two benches are reported to come together and are mined as one.

Section of coal bed in Francisco mine.

	Ft.	In.
Shale.		
Bony coal		6
Coal		7
Shale		1½
Coal	2	2
Shale.		
Total coal	3	3

Section of coal bed in Piedmont mine.

	Ft.	In.
Shale.		
Coal		7½
Shale		1
Coal		9
Shale		1½
Coal	3	2
Total coal	4	6½

The partings are said to disappear and the coal is reported to be about 7 feet thick in the southwestern part of the Piedmont mine. West of the Piedmont mine this bed is not worked and the dip carries it beneath Purgatory River near the bridge north of Sopris.

In the vicinity of Sopris the lowest group of coals consists of a varying sequence of six or eight beds from 1 to 7 feet thick within a zone of 250 feet above the base of the formation. These coal beds thicken and thin out characteristically. The most important is the one worked at the Sopris mine (No. 15) of the Colorado Fuel and Iron Company. This bed is about 190 feet above the Trinidad sandstone, and the mine workings show that it varies considerably in thickness and contains a number of partings. The following section was measured in room 3, entry 17 west:

Section of coal bed in Sopris mine.

	Ft.	In.
Sandstone roof.		
"Iron slate"		8
Coal		3½
Coal, bony		4½
Coal		9
Coal, bony		1½
Coal		5½
Coal, bony		1½
Coal		8
Coal, bony		1
Coal		9
Shale.		
Total coal	3	7½

In part of the mine, as shown below, there is a good body of coal separated by a thin bed of sandstone, which in places is too thick to permit the economical working of the entire bed.

Section of coal bed in Sopris mine.

	Ft.	in.
Shale.		
Coal	2	2
Shale or bone		9
Coal		9
Sandstone		8
Shale or bone		6
Coal	4	3
Shale.		
Total coal	7	2

In the La Belle mine (No. 14) of the Rocky Mountain Fuel Company, at approximately the same horizon, the following section was measured:

Section of coal bed in La Belle mine.

	Ft.	in.
Shale.		
Coal	4	
Shale		6
Coal		6
Shale.		
Total coal	4	6

The McLaughlin mine (No. 22), near Purgatory River, is on a bed at about the same horizon. The coal bed in this mine measures as follows:

Section of coal bed in the McLaughlin mine.

	Ft.	in.
Shale.		
Coal	2	3
Coal, bony		4
Coal		9
Bone		3
Coal	1	9
Shale		1
Coal		7
Shale.		
Total coal	5	8

North of Purgatory River, near the mouth of Reilly Creek, the recently opened Cokedale mine (No. 23) of the Carbon Coal and Coke Company is on a bed in the lower coal group about 220 feet above the Trinidad sandstone. The position of this bed, therefore, corresponds approximately to that of the Sopris coal. The Cokedale bed varies considerably in thickness and has the reputation of being a dirty coal. The following section was measured in room 26, entry 4 west:

Section of coal in Cokedale mine.

	Ft.	in.
Shale.		
Coal, bony		5½
Coal	1	2
Coal, bony		4
Coal		8
Coal, bony		2½
Coal		11
Coal, bony		2
Coal		4½
Shale		4
Coal	1	6
Shale		4
Coal		10
Coal, bony		3½
Shale.		
Total coal	6	11

Between Cokedale and Trinidad there are a number of prospect pits on various beds of coal belonging to the lower group, but only a few small mines. So far as known, the coal is thinner here than in other parts of the field. The following measurements illustrate the conditions:

Sections of coal bed between Cokedale and Trinidad.

NE. ¼ sec. 28, T. 33 S., R. 64 W. (No. 17).

	Ft.	in.
Shale.		
Coal	2	2
Shale	1	2
Coal		8
Shale.		
Total coal	2	10

NE. ¼ sec. 16, T. 33 S., R. 64 W. (No. 18).

	Ft.	in.
Shale.		
Coal	2	4
Coal, bony		8
Shale		2
Coal, bony		4
Shale		3
Coal		5
Shale.		
Total coal	3	9

SW. ¼ sec. 10, T. 33 S., R. 64 W. (No. 19).

	Ft.	in.
Shale.		
Coal, bony		3
Clay		½
Coal, bony		5
Coal	1	3
Shale		4
Coal	1	9
Shale.		
Total coal	3	8

Keystone mine, NE. ¼ sec. 10, T. 33 S., R. 64 W. (No. 20).

	Ft.	in.
Shale.		
Coal		9
Bone		5
Coal		11
Shale		1½
Coal	2	2
Shale.		
Total coal	3	10

In the SW. ¼ sec. 2, T. 33 S., R. 64 W. (No. 21), the coal is 2 feet 10 inches thick and has a shale roof and shale floor.

North of Trinidad the coal beds are thicker and there are a number of important mines. Several prospects at the head of Powell Canyon, in the SE. ¼ T. 32 S., R. 64 W., show more than 4 feet of coal. At the Baldy, a small mine without railroad connection in the SE. ¼ sec. 23, T. 32 S., R. 64 W., the following section was measured:

Section of coal bed in Baldy mine (No. 51).

	Ft.	in.
Shale roof.		
Coal	3	2
Shale		3
Coal	1	1
Shale		3
Coal		11
Shale.		
Total coal	5	2

The Mount Pleasant, in the NW. ¼ sec. 36, T. 32 S., R. 64 W., is another small mine without railroad connection. The bed worked is about 80 feet above the Trinidad sandstone.

Section of coal bed in Mount Pleasant mine (No. 52).

	Ft.	in.
Shale roof.		
Coal and bone		3
Shale		4
Coal	2	10
Shale		2
Coal		8
Shale.		
Total coal and bone	3	9

The Bowen mine of the Victor Fuel Company, in secs. 24 and 25, T. 32 S., R. 64 W., is one of the large producers of the Trinidad field. The mine is situated on the Trinidad sandstone bench 300 feet above the camp, which is in the Pierre shale valley. The workings are reached by a gravity plane connected with the Colorado and Southern Railway.

Section of coal bed in Bowen mine (No. 54), room 11, entry 2 N. 6 E.

	Ft.	in.
Coal	3	8½
Shale		½
Coal	1	
Shale		1
Coal		10
Shale		3
Coal	1	1
Total coal	6	7½

The Suffield mine (No. 55) of the Green Cañon Coal Company occupies a position similar to that of the Bowen, being located on a bench a few hundred feet above the mining town at the base of the cliffs. This mine was not in operation when visited in 1908, and a section of the coal bed was not obtained. The mining camps at Bowen and Suffield are subject to the disadvantage of having no local water supply, and water for both camps is hauled by train from Trinidad.

Stream erosion has so dissected the coal measures in the northern half of T. 32 S., R. 64 W. that the outcrop of the beds is extremely intricate. A number of openings on the coal have been made in Tingley and Chicosa canyons, in which the Forbes (Cox) and Majestic mines are located. The coal bed here, as usual, outcrops in the slope above the Trinidad sandstone escarpment, necessitating the construction of gravity tramways to reach the mines. A branch of the Colorado and Southern Railway extends up Tingley Canyon to the tipple of the old Forbes property, now known as the Cox mine (Nos. 56–58), operated by the Chicosa Fuel Company.

The principal coal occurs about 50 feet above the Trinidad sandstone. The following measurements were made at the Cox mine:

Sections of coal bed at the Cox mines.

SW. ¼ sec. 10, T. 32 S., R. 64 W. (No. 58).

Shale.	Ft.	in.
Coal	5	1
Shale		2
Coal	2	2
Shale		10
Coal	1	9
Shale.		
Total coal	9	

NW. ¼ sec. 15, T. 32 S., R. 64 W. (No. 56).

Shale.	Ft.	in.
Coal	4	1½
Shale		6
Coal	1	8
Shale.		
Total coal	5	9½

The Majestic mine (No. 59) of the Continental Fuel Company was not being worked when visited in 1908, and the coal bed, which is the same as that worked at the Cox mine, was not measured.

Little is known of other beds in the lower coal group between Cokedale and Majestic. In that area, however, at least one workable bed appears to be everywhere present, although it varies considerably in thickness and position. North of the Majestic mine to the north end of the field two or more beds of workable thickness are known in the lower group, although generally at any locality only one is worked, and the beds thicken and thin out irregularly.

The Ludlow mine (No. 60) of the Huerfano Coal Company and the Greenville mine (No. 61) of the Cedar Hill Coal and Coke Company are situated on the bench above the Trinidad sandstone and are reached by gravity planes which connect with the Colorado and Southern Railway. Three beds are present in this vicinity, as shown by the following section at the Ludlow mine:

Section of coal beds in NW. ¼ sec. 32, T. 31 S., R. 64 W.

	Ft.	in.
Coal		6
Shale		½
Coal	2	3½
Interval	12–20	
Coal	5	

	Ft.	in.
Interval	44	
Coal	1	4
Shale		7
Coal	3	3
Shale.		
Interval	25	
Sandstone, Trinidad.		
Total coal	12	4½

The following measurement was made at the Greenville mine, which is on the lowest bed of the group:

Section of coal bed at Greenville mine (No. 61).

	Ft.	in.
Shale.		
Coal	1	
Shale		1
Coal	4	3
Shale.		
Total coal	5	3

In Road Canyon the Berwind and Tabasco mines are being worked by the Colorado Fuel and Iron Company, in conjunction with the coke ovens at Tabasco. These mines are located on the lowest bed of the lower coal group where it passes beneath the surface; farther up the canyon the same bed is being opened at the Toller shaft. The Trinidad sandstone is conspicuous in this region, and the coal beds occur in a zone of about 130 feet of shale and thin sandstone lying between the Trinidad and a massive bed of conglomeratic sandstone. Two beds are well developed here, but only the lowest is worked. The following section shows the local stratigraphy.

Section of rocks in Road Canyon at Tabasco.

	Feet.
Sandstone, massive conglomeratic, siliceous pebbles up to 1 inch.	20+
Shale and thin sandstone, including sill	60
Coal, Hastings bed (?)	8±
Shale and thin sandstone	60
Coal, Berwind bed	6±
Shale and thin sandstone	5–25
Sandstone, Trinidad.	

In the Berwind mine a parting of shale from half an inch to 6 inches thick usually occurs about 10 or 12 inches beneath the top of the coal bed, and the coal below the parting is reported to vary between 48 and 70 inches in thickness. In some places the roof is shale and in others it is sandstone. A prospect on the upper Hastings (?) bed above the Tabasco coke ovens shows 7 to 8 feet of good coal, but the bed has not been developed.

The Toller shaft (No. 64) of the Cedar Hill Coal and Coke Company is one of the few shafts in the Trinidad field and is an indication of the future development of the field. New exploitation will tend to be carried on by shafts by means of which the reserves of the interior of the field will be reached after the choice property along the coal outcrop has been taken up or exhausted. The Toller shaft, reported to be 360 feet deep, was sunk in 1908, but the mine was not in operation in that year.

Little is known of the coal between Road Canyon and Canyon de Agua, but in the latter is located the Hastings mine (No. 67) of the Victor Fuel Company, one of the important mines of the field. In the vicinity of Hastings the lower coal group consists of one to six varying beds of coal within a zone of 150 feet above the Trinidad sandstone, but at present only one bed is worked. The following section was measured in the Hastings mine:

Section of coal bed in Hastings mine.

	Ft.	in.
Shale.		
Coal	3	8
Sandstone		1
Coal	1	8
Shale.		
Total coal	5	4

The Hastings bed is reported to thin toward the west, and mining on it may have to be abandoned in that direction. Tests show that another bed, 40 feet beneath the Hastings, corresponding to the Berwind coal, has a thickness in this area of about 5 feet.

Little prospecting has been done for a few miles north of Hastings, but along Apishapa River the coals are better known. There the lower group consists of three to six varying beds of coal between 1 and 6 feet thick, but usually only one workable bed is known. This is named the Peerless bed, from the Peerless mine (No. 85). It ranges as a rule between 3 and 6 feet in thickness and occurs from 50 to 70 feet above the Trinidad sandstone. The Peerless mine was abandoned after striking a strong flow of water, which in 1908 was reported to be pumped to the mining camps at Hastings, Delagua, and Berwind.

The Empire mine (No. 86), also on the Peerless bed, was not working in 1908. The following section was measured by O. J. Bowman in 1907:

Section of coal bed in Empire mine.

	Ft.	in.
Shale.		
Coal	3	8
Sandstone		2½
Coal	1	2
Shale.		
Total coal	4	10

The following sections of coal in the lowest group were measured in prospect pits about a mile south of Apishapa River at the localities indicated on the map by Nos. 78 to 81:

Sections of coal beds in prospect pits south of Apishapa River.

No. 78.

Shale.	Ft.	in.
Coal, shaly	2	
Coal	1	6
Bone	1	4
Coal		7
Total coal and bone	5	5

No. 79.

Shale.	Ft.	in.
Coal, coked	1	6
Shale	2	3
Coal		10
Total coal	2	4

No. 80.

Shale.	Ft.	in.
Coal, coked, graphite	2	1
Shale	1	1
Coal		3
Shale		5
Coal		7
Shale.		
Total coal	2	11

No. 81.

Shale.	Ft.	in.
Coal	2	
Shale		1½
Coal	3	4
Total coal	5	4

North of the Peerless mine the Peerless bed is reported to have been struck in the Brodhead shaft (No. 95) at a depth of 274 feet. A pocket of coal about 6 feet thick is said to have been worked in this shaft, but further working was stopped, the coal being destroyed by a sill of igneous rock. Other mines in this vicinity are on the middle group of coals described on pages 407–409.

The lower group of coal beds outcrops in the face of the cliffs above the Pierre shale lowlands between Aguilar and the north end of the Trinidad district at the county boundary line, as shown on the map. Coal beds have been opened at several prospects and small mines, where the following sections were measured. Immediately north of Aguilar the lower coal group appears to be poorly developed, as indicated by a measurement in a prospect (No. 88).

Section of coal beds in SE. ¼ sec. 21, T. 30 S., R. 65 W.

Shale.	Ft.	in.
Coal	1	3
Shale		10
Coal		8
Total coal	1	11

A short distance farther north, however, the coal-bed measures 3 feet 6 inches in the Jewel mine (No. 89), in the northeast quarter of the same section. In a prospect (No. 90) in the SE. ¼ sec. 16, T. 30 S., R. 65 W., 3 feet 7 inches of coal is exposed.

At the Southwestern mine (No. 91), in the NE. ¼ sec. 16, T. 30 S., R. 65 W., the following section was measured, the principal coal being approximately at the horizon of the Peerless bed:

Section of coal bed at Southwestern mine.

	Ft.	in.
Shale.		
Coal	3	
Shale		3
Coal	1	3
Shale.		
Interval	65	
Shale.		
Coal	1	3
Shale	1	
Sandstone		4
Shale and bony coal	1	3
Sandstone, Trinidad.		

The following section shows the stratigraphy of the lower coal group in the northern part of the Trinidad district:

Sections of coal beds in northern part of Trinidad district.

SE. ¼ sec. 9, T. 30 S., R. 65 W. (No. 92).

	Ft.	in.
Sandstone.		
Shale	10	
Coal	3	10
Sandstone and shale	35	
Coal	2	1
Shale	1	
Coal		11
Sandstone and shale	20	
Coke	1	
Shale and sandstone	3	
Coal		9
Shale	1	1
Coal	1	2
Sandstone and shale	55	
Coal	1	7
Shale	3	
Sandstone, Trinidad.		

SE. ¼ sec. 29, T. 29 S., R. 65 W. (No. 104).

	Ft.	in.
Coal	1	2
Shale	10	
Coal	3	6
Sandstone and shale	40	
Coal	1	4
Shale		1
Coal	2	2
Shale and sandstone	12	
Coal		10
Sandstone and shale	15	
Coal	1	
Shale	5	
Sandstone, Trinidad.		

These sections show that the principal coal bed occurs 125 feet above the Trinidad sandstone in No. 92 and 78 feet above in No. 104.

The Rapson mine (No. 93) of the Rapson Coal Mining Company was connected with the Colorado and Southern Railway by a branch in 1908. The bed mined is reported to be about 100 feet above the Trinidad sandstone. The following section was measured here:

Section of coal bed in Rapson mine, face of entry No. 3 south.

	Ft.	in.
Shale.		
Coal, bony		5
Coal	1	11½
Coal, bony		2
Coal	1	4
Shale.		
Total coal	3	10½

In the Thomas mine (No. 94) of the Wichita Coal and Material Company, connected with the Colorado and Southern Railway by the same branch as the Rapson mine, the following section was measured:

Section of coal bed in Thomas mine.

	Ft.	in.
Shale.		
Coal	2	9
Shale		½
Coal		1
Shale		1½
Coal		7
Shale.		
Total coal	3	5

The Black Diamond mine (No. 103) of the Cedar Hill Coal and Coke Company is situated on the bench above the Trinidad sandstone and is connected with the Colorado and Southern Railway by a short spur. The coal bed is about 80 feet above the Trinidad sandstone. The following section was measured in this mine:

Section of coal bed in Black Diamond mine.

	Ft.	in.
Shale.		
Coal		6
Shale		5
Coal		11
Shale		8
Coal	2	3
Shale.		
Total coal	3	8

MIDDLE COAL GROUP.

Above the lower coal group, which includes a zone of about 250 feet of strata above the top of the Trinidad sandstone, there is a barren zone of 200 to 300 feet of beds in which no workable coal has yet been found, although a few diamond-drill records show the presence of thin coaly layers. In places, as stated on page 387, a varying bed of conglomerate and conglomeratic sandstone lies immediately above the lower coal group. This interval of generally barren strata separates the lower and middle coal groups. The division is useful only for purposes of description and classification, for, as already stated, the entire lower portion of the "Laramie" formation is coal bearing. The middle group of coal beds is confined to about 200 feet of strata which lie between 400 and 600 feet above the top of the Trinidad sandstone. This group is not nearly so persistent as the lower group, and workable beds belonging to the middle group are known at only a few rather widely separated localities. No attempt, however, has been made by prospecting to trace the coal beds of the middle group from one area to another where these coals are being mined.

In the Raton field, adjacent to the New Mexico-Colorado boundary, coal beds occurring in the general stratigraphic position of the middle group of the Trinidad field, according to Willis T. Lee, are well developed and are worked at the Blossburg and Yankee mines and at other places. But in Colorado natural exposures are poor on the wooded talus-covered slopes of Raton Mesa. Nevertheless, from one to four varying beds of coal, lying between 400 and 450 feet above the Trinidad sandstone and ranging from 2 to 4 feet in thickness, are known in this area. At only a single locality, the Fishers Peak mine (No. 8), on the north slope of Raton Mesa, is one of the middle coal beds worked.

The Fishers Peak mine is situated in the NW. ¼ sec. 32, T. 33 S., R. 63 W., about 3 miles southeast of Trinidad, with which it is connected by wagon road. The coal bed is estimated to be 425 feet above the Trinidad sandstone and varies in thickness from 6 inches to 4 feet, as shown by measurements in the mine. The following section was measured in the mine 300 feet from the entrance:

Section of coal bed in Fishers Peak mine.

	Ft.	In.
Shale roof.		
Coal	1	2
Shale		1
Coal		5
Shale		4
Coal		8
Coal and bone	1	4
Shale floor.		
Total coal and bone	3	7

Nothing is known of the middle group of coal beds between the Fishers Peak mine and Apishapa River, except that a few thin beds have been noted in diamond-drill records which the writer is not at liberty to describe. North of Apishapa River, however, as far as the boundary between Las Animas and Huerfano counties, the middle group of coals is locally well developed and mines on these beds are worked by the Las Animas, Green Cañon, Primrose, and Rugby coal companies (Nos. 96–100).

Albert G. Brodhead, who has done much to exploit this region, states that diamond drilling shows the presence of several varying beds of coal between 500 and 600 feet above the Trinidad sandstone. Three beds are reported to average about 4 feet each, although the thickness in places is reduced by partings of shale. Difficulty in mining has been caused by a local flexure that has caused the strata in places to dip steeply, but beyond the flexure the beds have the normal low westward inclination, and in places sills of igneous rock have destroyed the coal. The following sections were measured in the Green Cañon mine:

Sections of coal bed in Green Cañon mine.

	Ft.	in.
Sandstone.		
Coal	2	10
Shale		1
Coal	2	1
Shale.		
Total coal	4	11

	Ft.	in.
Sandstone.		
Coal	2	4
Shale		6½
Coal	1	8
Total coal	4	

The mines of the Las Animas and Green Cañon companies are reached by a branch line of the Colorado and Southern Railway, which passes through the town of Aguilar and up Gonzales Creek.

The Primrose (No. 99) and Rugby (No. 100) mines, situated at the extreme north end of the Trinidad district, are on the same bed of coal. Two beds about 60 feet apart are present, but the upper bed, which is reported to be about 3 feet thick, is not worked. The lower of the two beds is mined. It averages about 4 feet in thickness and is estimated to be 500 feet above the Trinidad sandstone. In the Primrose mine a parting of shale, said to average 4 inches in thickness, is present about midway in the bed, but in the Rugby mine the parting has not been reported. The following section was measured in the Primrose mine:

Section of coal bed in Primrose mine, room 3, entry 1½ north.

	Ft.	in.
Shale.		
Coal		11
Shale		1
Coal	3	4
Shale.		
Total coal	4	3

The Primrose and Rugby mines are connected by a tramway with a branch of the Colorado and Southern Railway.

These coal beds of the middle group have not been traced south of the Brodhead property or north of the Rugby mine.

UPPER COAL GROUP.

The upper coal group consists of varying coal beds (from one to six beds, usually more than 18 inches thick) that in general lie between 800 and 1,200 feet above the top of the Trinidad sandstone. This group is not in all places clearly separable from the underlying groups, but in general it can be recognized without difficulty. In some sections thin, commercially unimportant layers of coal occur at varying intervals between the middle and upper groups, as was also noted between the middle and lower groups. These sporadic occurrences of thin beds of coal between the major groups emphasize the fact that the lower 1,200 feet or so of the "Laramie" is coal bearing, but it is nevertheless a fact that the known beds of workable thickness fall into one of the three groups here described. The upper group of coals, like the middle group, is not so persistent as the lower group, and workable beds in it are known only in certain areas. The upper group of coals appears to be confined to the Trinidad district and to the southern interior portion of the field. Figure 6 shows the usual topographic and stratigraphic occurrence of the groups.

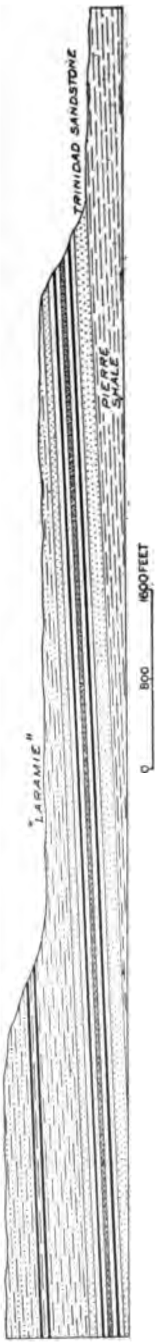

FIGURE 6.—Section of rocks near Delagua and Hastings, Colo., showing upper and lower coal groups.

In the Trinidad district the best-known occurrences of the upper group of coal beds are at Delagua, on Apishapa River above Aguilar, and in Road Canyon. Coal beds have not been traced continuously from one of these areas to another, but there is little doubt that the coal group is continuous, even if no individual bed extends through all three localities. In prospecting to determine the possible connection between Road Canyon and West Canyon in the Purgatory district the boundary line between the areas in which the top of the Trinidad sandstone is greater and less than 1,000 feet beneath the surface (see Pl. XX) may be of assistance, for it marks this approximate horizon.

The Delagua mine (No. 68) of the Victor Fuel Company, in sec. 15, T. 31 S., R. 65 W., is one of the large mines of the Trinidad field. The bed worked is estimated to be 850 feet above the Trinidad sandstone. The thickness of the bed varies from place to place, as well as the number and thickness of the partings of shale. At one place 5 feet 10 inches of clean coal was measured, while a few hundred feet away the bed contained 2 inches of shale 6 inches from the roof and 4 inches of shale 3 feet 3 inches from the roof. The following section was measured in the Delagua mine:

Section of coal bed in Delagua mine.

	Ft.	In.
Shale.		
Coal		8
Shale		6
Coal	2	9
Shale		10
Coal	2	6
Shale.		
Total coal	5	11

The Delagua mine is connected by rail with the Hastings mine and thence with both the Colorado and Southern and the Denver and Rio Grande railroads.

The upper group of coals is worked in a small way at the Bear Canyon mine (No. 65) in the NW. ¼ sec. 11, T. 32 S., R. 65 W., where two beds 30 feet apart are exposed, as shown in the section:

Section of coal beds at Bear Canyon mine.

	Ft.	in.
Shale.		
Coal		11
Shale		6
Coal	1	
Shale		1
Coal	2	4
Interval	30	
Coal	2	
Bone		3
Coal	2	
Total coal	8	3

The Bear Canyon mine has no direct railroad connection, but the property is only about a mile from the end of the branch railroad at the Toller shaft.

As shown on the map (Pl. XX), the upper coal group has been prospected at a number of localities on Apishapa River, where measurements show coal beds between 3 and 5 feet thick. Although a railroad could easily be constructed up the broad river valley, the coal here remains undeveloped.

WALSENBURG DISTRICT.

The Walsenburg district includes the area contiguous to the outcrops of coal beds along the eastern and northern margin of the Trinidad field, north of the boundary line between Las Animas and Huerfano counties. Near the county line the coal outcrops in the face of steep cliffs, but farther north the cliffs are less prominent and the greater part of the Walsenburg district is a relatively low-lying area of little relief. The Trinidad sandstone is generally inconspicuous and the coal-bearing "Laramie" formation is succeeded by the Poison Canyon formation, which at the northwest end of the area overlaps the coal outcrop and conceals the probable extension of the Trinidad coal field in Huerfano Park. Along the eastern margin of the district the strata dip about 3° W., but the dip decreases westward to almost nothing in the center of the basin. At the north end of the field the strike curves around to the west and finally turns southwest, conforming to the general structure of the region, and at the northwest end of the field the dip is about 15° SE. Only the lower group of coal beds is worked in the Walsenburg district. The middle group apparently is not well developed here and the upper group was either never deposited or has been eroded or covered by the overlap of younger deposits.

The lower group in the Walsenburg district consists of two to eight beds more than 18 inches thick within a zone of 250 feet above the top of the Trinidad sandstone. In the vicinity of Walsenburg three workable beds are present, which are known as the Cameron, Walsen, and Robinson beds, but these beds are not persistent and where they have not actually been traced correlation should not be assumed.

In the vicinity of Santa Clara Creek, in the southern part of the Walsenburg district, there are several large mines with railroad connections. At the Santa Clara or new Rouse mine (No. 106) of the Colorado Fuel and Iron Company a bed of coal reported to range from 5 feet to 6 feet 8 inches in thickness is worked. This is said to be the middle one of three workable beds in this area. The following section was measured at the face of the eighth east entry near the end of the main slope:

Section of coal bed in Rouse mine.

	Ft.	in.
Shale.		
Coal	2	6
Sandstone, shaly		4½
Coal	3	3½
Shale.		
Total coal	5	9½

At the Midway mine (No. 107) of the Chicosa Fuel Company and the Pryor mines (Nos. 108–110) of the Union Coal and Coke Company three beds of coal are worked. These are locally known as the Cameron (lowest), Walsen (middle), and Robinson (upper) beds, the names of coals in the vicinity of Walsenburg being used, but the beds have not been traced between these places, and it is by no means certain that they are continuous. The following measurements were made at the Pryor mines:

Section of coal beds at the Pryor mines.

		Ft.	In.
Sandstone, irregular streak of "draw slate"			1–3
Coal		1	8
Parting	upper bed		6
Coal		3	3
Parting			4
Coal		1	2
Interval		35±	
Shale.			
Coal	middle bed	2	4
Coal, bony			4–10
Sandstone			2
Coal		3	4
Shale.			
Interval		30±	
Coal, lower bed		4	6
Total coal		16 to 17	7 1

The lowest coal bed lies practically on or within a few feet above the Trinidad sandstone.

A zone of normal faults is present in the vicinity of these mines, the downthrow being on the west. At the Rouse mine the displacement is the greatest reported—85 feet. At the Midway mine the throw is not so great, but is enough to cause a peculiar condition. The slope enters on the lowest bed, but at a distance of about 800 feet a fault is encountered with just sufficient throw, 32 feet, to bring the overlying middle coal bed abreast of the lowest coal bed, as shown in figure 7. Figure 8 illustrates a small fault in the Berwind mine.

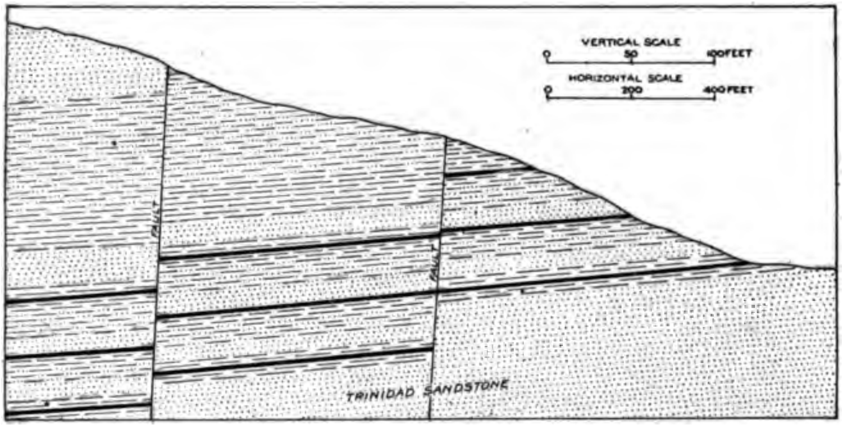

FIGURE 7.—Faulted coal beds in Midway mine, Trinidad coal field, Colorado.

The Hezron (No. 111) and old Rouse (No. 115) mines of the Colorado Fuel and Iron Company were formerly large producers with railroad connection, but neither mine was worked in 1908. The coal bed in the Hezron mine, reported to be 5 feet thick but to contain a number of varying partings, is about 170 feet above the Trinidad sandstone. R. C. Hills states that at the old Rouse mine the lowest bed has a thickness of 6½ to 7 feet.

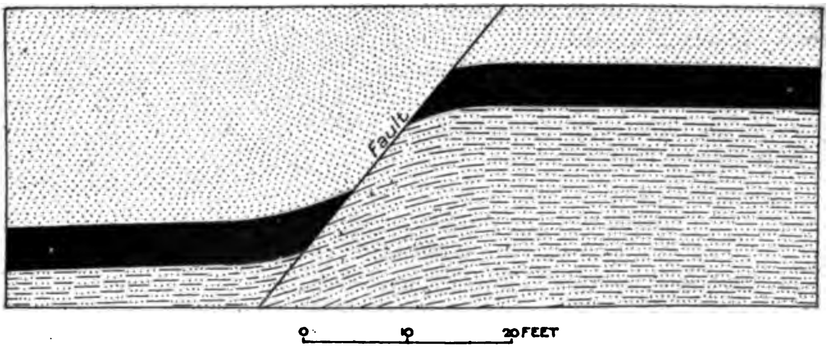

FIGURE 8.—Fault in Berwind mine, Trinidad coal field, Colorado.

At a prospect in sec. 35, T. 28 S., R. 66 W. (No. 116), the coal is 4 feet thick, and at another, in sec. 34, T. 28 S., R. 66 W. (No. 117), it is 2 feet 3 inches thick. The roof and floor are shale at both these prospects, which lie northwest of the old Rouse mine.

The Round Oak (No. 118), in sec. 27, T. 28 S., R. 68 W., a small mine without railroad connection, is, so far as the writer is aware, on the thinnest bed of coal that is being mined in the Trinidad field, a measurement showing only 2 feet 5 inches of coal. It is well known, however, that in many localities beds of coal only 18 inches thick are profitably worked. An upper bed of coal on the Round Oak property measures 4 feet 5 inches.

The three workable coal beds in the vicinity of Walsenburg are shown in the following section:

General section of coal beds near Walsenburg.

	Feet.
Coal, Robinson bed	6–7
Interval	60
Coal, Walsen bed	6
Interval	35
Coal, Cameron bed	2–4
Shale	5
Sandstone, Trinidad.	

In the Ravenwood mine (No. 120), in the SE. ¼ sec. 21, T. 28 S., R. 66 W., on the Cameron bed, the following section was measured:

Section of coal bed in Ravenwood mine.

	Ft.	In.
Shale.		
Coal	2	8
Parting, thin.		
Coal		6
Shale.		
Total coal	3	2

At the new Cameron mine (No. 122), 1 mile south of Walsenburg, the Colorado Fuel and Iron Company has recently opened a mine on the Cameron bed. At the entrance to the workings 3 feet 7 inches of coal, with 2 feet of shale lying between it and the Trinidad sandstone, is exposed, but about 1,500 feet down the slope the bed has a thickness of only 2 feet.

In the valley of Cuchara River immediately west of Walsenburg mines from which the coals are named have been worked for many years on all three beds. Measurements could not be made in the old Cameron mine, but the following was made in the Walsen mine:

Section of coal bed in Walsen mine (No. 123).

	Ft.	In.
Shale.		
Coal		9
Coal, bony		8
Coal	2	9½
Clay		2½
Coal	1	6
Shale.		
Total coal	5	8½

In the Robinson mine (No. 125), in the eighth cross entry off the eighth north entry, there is 7 feet of coal with shale roof and floor.

The Huerfano mine (No. 126), in the NW. ¼ sec. 8, T. 28 S., R. 66 W., reaches the coal by means of a shaft 50 feet deep.

A great dike extending across the country for many miles[a] cuts across the outcrop of coal about a mile northwest of Walsenburg, and different names have been given to the three workable coal beds north of the dike. The lowest bed is there known as the Maitland, the middle bed as the Lennox, and the upper as the Monarch. Drill records and the experience of operators in this vicinity, however, show that the three beds are not persistent and that it is a mistake to apply these names to beds at any considerable distance from the vicinity of the type localities, the Pictou and Maitland mines, unless their identity has been established.

It is reported that at the Toltec mine (No. 128) of the Northern Coal and Coke Company the upper and middle beds are worked. At the Pictou mine (No. 129) of the Colorado Fuel and Iron Company all three beds are worked, but about 2,500 feet in from the mouth of the slope on the upper bed the upper and middle coalesce into a single bed 10 feet thick. At the entrance to the mine the upper and middle beds are 30 feet apart and the middle and lower beds 15 feet apart; and at the junction of the upper and middle the united bed is 20 feet above the lower. (See fig. 9.)

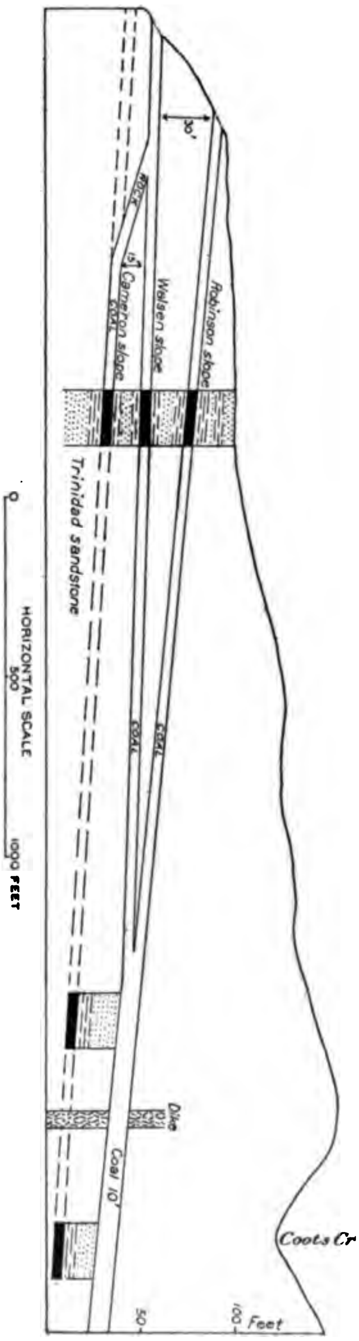

FIGURE 9.—Section in Pictou mine, Pictou, Colo., showing coalescence of beds. By J. S. Thompson, superintendent.

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[a] Walsenburg folio (No. 68), Geol. Atlas U.S., U.S. Geol. Survey, 1900.

The Maitland mine (Nos. 132–133) of the Victor Fuel Company, in sec. 31, T. 27 S., R. 66 W., is on the lower two beds, the Maitland and Lennox, which are separated by an interval of 10 to 30 feet, the Maitland bed lying practically on the Trinidad sandstone. The Maitland bed is reported to range between 4 feet 6 inches and 6 feet in thickness, with a varying parting up to 5 inches thick. The Lennox bed is from 3 to 4 feet thick, with but little bone. The workings of the Maitland and Pictou mines are connected by means of the Champion and Sunshine mines, which are much smaller producers.

North of the Maitland mine there are a few small workings, but the next large mine is the Piñon (No. 136) of the Rocky Mountain Fuel Company, in sec. 23, T. 27 S., R. 67 W. Two beds about 140 feet apart are worked in this mine. The upper bed, which is worked from a slope, is reported to run from 6 to 7 feet in thickness, with a parting from 4 to 18 inches thick in the middle of the bed. This slope was not in operation when visited in 1908. The lower bed, which lies practically on the Trinidad sandstone, is entered from a shaft 120 feet deep. The following section was measured here:

Section of lowest coal bed at Piñon mine.

	Ft.	In.
Shale.		
Coal, bony		10
Coal	4	2
Shale.		
Total coal and bone	5	

This shaft and those at the Huerfano and Toller mines are the only shafts at present being operated in the Trinidad field.

At the extreme north end of the field several mines have recently been opened which, like all the mines north of Walsenburg, have railroad connection by a branch of the Denver and Rio Grande, extending northwest to Walsenburg along the outcrop of the principal coal beds.

At the Laramie mine (No. 139), in the NE. ¼ sec. 9, T. 27 S., R. 67 W., the following section was measured:

Section of coal bed in the Laramie mine.

	Ft.	In.
Shale.		
Coal	5	6
Shale		1
Coal		10
Total coal	6	4

At Strong the Sunnyside mine (No. 140) of the Sunnyside Coal Mining Company is on a bed which lies within a few feet of the Trinidad sandstone. The following section was measured in the mine.

Section of coal bed at face of main slope in the Sunnyside mine.

	Ft.	In.
Sandstone.		
Shale		8
Coal	5	5
Bone		1
Coal	1	8
Shale.		
Total coal	7	1

An irregular shale parting is said to be of common occurrence within 18 inches of the roof.

It is reported that a mile southwest of Strong, at the Tioga mine (No. 142) of the Minnequa Coal Company the 7-foot lower bed worked at the Sunnyside mine has a thickness of only 4 feet and the upper bed, which at Strong is the thinner, is 6 feet thick and is the better of the two. A slope on the lower bed at Tioga has been abandoned, and one on the upper bed, which is about 50 feet above the lower, is being opened. The coal here dips 15° S. 45° E.

Southwest of the Tioga mine the surface is occupied by silt and the coal must be prospected by drilling.

At the Big Four mine (No. 143), opened in 1908, two beds of coal have been found, 48 feet apart. The upper bed, as at the Tioga mine, is being worked, but the lower bed is reported to be dirty and variant. In this mine 6 feet 10 inches of coal was measured. The dip of the beds is 12° S. 60° E.

Practically nothing is known of the coal between the Big Four mine and the Oakdale mine on the opposite side of the basin (p. 419). In this area the coal-bearing rocks are covered by an overlap of Tertiary and Quaternary deposits, and northwest of La Veta igneous rocks forming Veta and Dike mountains interrupt the continuity of the coal field. From the general structure of the region it seems probable that the coal measures extend northwestward in the synclinal area of Huerfano Park where the "Laramie" formation is covered by Eocene and later strata. Although the occurrence of coal in this area must be determined by the drill, it is an inviting field for exploitation.

WESTERN OUTCROP.

LA VETA DISTRICT.

The La Veta district includes the area contiguous to the coal outcrop along the northwestern margin of the Trinidad coal field from its farthest known extent on the flanks of Veta Mountain southward to the vicinity of the Huerfano-Las Animas county boundary line, where the coal outcrop is interrupted by a mass of intrusive igneous rock.

In this area the coal-bearing rocks in general dip northeastward at angles ranging from 10° to 65°, but at the northwest end of the district there is a zone in which the rocks are folded in an unsymmetrical anticline and syncline. Here, as throughout the western margin of the Trinidad field, the steep dip causes the coal to outcrop in a comparatively straight line that is in strong contrast to the intricate outcrop along the eastern border of the field, where the dip is low. (See Pl. XX.) The Pierre shale occurs in a narrow strip west of the outcrop of the Trinidad sandstone, which is rather inconspicuous, and broadens out in the axis of the anticline northwest of La Veta. The "Laramie" formation occupies a somewhat wider belt and is unconformably overlain by the Poison Canyon formation.

The coal has not been thoroughly prospected in the La Veta district, although a number of openings have been made along the outcrop, as shown on Plate XX, and a few mines have been opened. Only the lower group of coal beds has been found in this district.

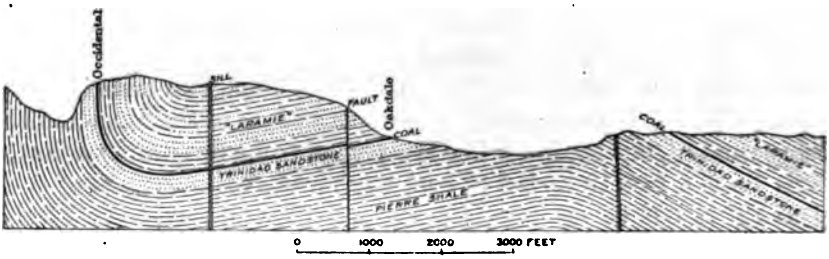

FIGURE 10.—Section between Occidental and Oakdale mines, northwest of La Veta, Colo.

The best-developed part of the La Veta district is in the subsidiary basin north of the Denver and Rio Grande Railroad, 7 miles northwest of La Veta. This is an unsymmetrical syncline about 3 miles long from northwest to southeast and a mile wide. The coal is cut off at the north end of the fold by the intrusion of the mass of igneous rock which forms Veta Mountain. On the western limb of the syncline the coal beds are almost perpendicular and in places are slightly overturned, but generally the dip is steep to the northeast. On the eastern limb the coal dips 15° SW. (See fig. 10.)

The Occidental mine (No. 146) of the Occidental United Metal and Coal Company, in sec. 9, T. 29 S., R. 69 W., when visited in 1908 was not in operation. The mine is connected with the Denver and Rio Grande Railroad by a long, winding tramway. The coal is reached by a tunnel about 300 feet long, which was begun in Pierre shale and was cut through the Trinidad sandstone, here almost perpendicular. Two beds of coal are present, about 45 feet apart. The lower bed, lying within 30 feet of the Trinidad sandstone, is reported to range from 6 to 8 feet in thickness and the upper bed from 3 to 4 feet. (See fig. 11.)

The Oakdale mine (No. 149) of the Oakdale Coal Company, located on the eastern limb of the detached basin in the SW. ¼ sec. 10, T. 29 S., R. 69 W., has recently been opened and in 1908 was the only shipping mine in the La Veta district. The bed worked lies about 30 feet above the Trinidad sandstone and averages possibly 7 feet 6 inches in thickness. At the foot of the slope 7 feet 4 inches of clean coal was measured. In the mine the coal is cut by a fault having a downthrow on the east of 22 feet. A number of prospects have been opened on the coal in the detached syncline, as shown on the map (Pl. XX), but there are as yet no other working mines there.

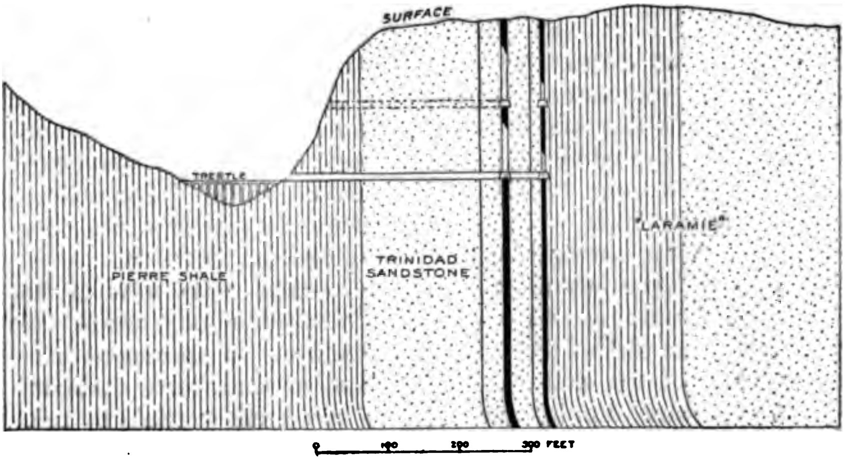

FIGURE 11.—Section at Occidental mine, west of La Veta, Colo.

The coal outcrop along the main western margin of the Spanish Peaks syncline west of La Veta has been prospected in a number of places and a few small mines have been opened, but railroad connection has not yet been extended to them. The following measurements show the thickness of the coal beds where they have been exposed:

Sections of coal beds west of La Veta.

NW. ¼ sec. 14, T. 29 S., R. 69 W. (No. 152).

	Ft.	In.
Sandstone.		
Coal		4
Sandstone		½
Coal	2	5
Sandstone.		
Total coal	2	9

SE. ¼ sec. 15, T. 29 S., R. 69 W. (No. 153).

	Feet.
Sandstone.	
Coal	3
Shale.	

SE. ¼ sec. 22, T. 29 S., R. 69 W. (No. 154).

Shale.	Ft.	In.
Coal	2	6
Shale	2	10
Coal	2	2
Total coal	4	8

Indian Creek mine, NW. ¼ sec. 2, T. 30 S., R. 69 W. (No. 155).

Sandstone.	Ft.	In.
Coal	1	8
Sandstone	4	
Coal	2	8
Total coal	4	4

NE. ¼ sec. 11, T. 30 S., R. 69 W. (No. 156).

Shale.	Ft.	In.
Coal	3	
Shale		6
Coal	3	
Total coal	6	

Springer tunnel, SE. ¼ sec. 11, T. 30 S., R. 69 W. (No. 157).

	Ft.	In.
Coal	1	6
Sandstone		1
Coal	1	4
Total coal	2	10

STONEWALL DISTRICT.

The Stonewall district includes the area contiguous to the coal outcrop along the western margin of the coal field from the vicinity of the Huerfano-Las Animas county boundary line, where the coal outcrop is interrupted by a mass of intrusive igneous rock, southward for a distance of about 17 miles to the entrance to the Tercio embayment, on South Fork of Purgatory River. In this area the coal-bearing rocks dip eastward at angles ranging from 25° to 70°.

The Pierre shale occupies a narrow lowland zone west of the "Laramie" formation and is cut by several dikes of igneous rock which strike parallel to the strata and stand out in prominent relief in the midst of the shale lowland. West of the Pierre shale the Dakota sandstone, dipping about 80° E. and being overlain by relatively soft beds, stands out as a conspicuous wall that is called the Stonewall and is a well-known local landmark. In the northern part of the Stonewall district, where the surface altitude is higher, Eocene beds, marked by a well-developed basal conglomerate, outcrop, but farther south these rocks have been eroded and the "Laramie" formation occupies the surface.

The lower group of coal beds has been prospected to some extent in the Stonewall district, but on account of the absence of railroads no mines have been opened. Little is known of the upper coal beds, except in the valley of Middle Fork of Purgatory River west of Vigil, where along the roadside a coal bed is exposed which probably lies about 1,000 feet above the Trinidad sandstone. Nothing is yet known of the middle group of coal beds in the Stonewall district.

The following measurements, beginning at the north and proceeding southward, show the thickness of the coal where it has been prospected in the Stonewall district.

Sections of coal beds in Stonewall district.

SW. ¼ sec. 25, T. 31 S., R. 69 W. (No. 48).

	Ft.	In.
Shale.		
Coal		2
Shale	1	9
Coal		3
Shale	1	6
Coal	3	4
Sandstone		1
Coal	2	3
Shale.		
Total coal	6	

SW. ¼ sec. 6, T. 32 S., R. 68 W. (No. 47).

	Ft.	In.
Shale.		
Coal	1	
Shale		2
Coal	3	11
Sandstone		1
Coal	1	10
Shale.		
Total coal	6	9

SW. ¼ sec. 6, T. 32 S., R. 68 W. (No. 46).

	Ft.	In.
Shale.		
Coal, shaly	1	4
Shale		1½
Coal	3	8
Sandstono		¼
Coal	1	8
Total coal	6	8

NE. ¼ sec. 18, T. 32 S., R. 68 W. (No. 45).

	Feet.
Shale.	
Coal	6
Shale.	

NW. ¼ sec. 20, T. 32 S., R. 68 W. (No. 44).

	Ft.	In.
Coke	5+	
Impure coke	1	6
Shale.		

SE. ¼ sec. 20, T. 32 S., R. 68 W. (No. 43).

	Ft.	In.
Shale.		
Coal	1	5
Shale		3½
Coal	1	4
Shale		1½
Coal	3	4+
Total coal	6	1+

NE. ¼ sec. 29, T. 32 S., R. 68 W. (No. 42).

	Ft.	In.
Coal	8	8+

SW. ¼ sec. 33, T. 32 S., R. 68 W. (No. 41).

	Ft.	In.
Shale.		
Coal, bony		7
Shale		8
Coal	6	6
Total coal	7	1

NW. ¼ sec. 4, T. 33 S., R. 68 W. (No. 40).

	Ft.	In.
Shale.		
Coal	2	8
Interval	150	
Coal	5	6
Shale.		
Total coal	8	2

Maxwell grant, three-fourths mile south of North Fork of Purgatory River (No. 39).

	Ft.	In.
Coal	1	
Shale	10	
Coal	1	
Shale	3	
Sandstone	5	
Coal	3	6
Shale.		
Total coal	5	6

West of Stonewall post-office, one-half mile north of Middle Fork of Purgatory River (No. 38).

	Ft.	In.
Shale.		
Coal	2	
Shale		4
Coal	2	2+
Interval	150	
Shale.		
Coal	3	
Clay		2
Coal		10
Clay		2
Coal	1	1
Interval	45	
Trinidad sandstone.		
Total coal	9	1

One-half mile south of Middle Fork of Purgatory River (No. 37).

	Ft.	In.
Sandstone.		
Coal	7	8
Shale.		

Two miles south of Middle Fork of Purgatory River (No. 36).

	Ft.	In.
Shale.		
Coal	3	6
Shale.		

TERCIO DISTRICT.

The Tercio district includes the area contiguous to the coal outcrop in the Tercio embayment and southwest of it to the Colorado-New Mexico boundary. The embayment is an anticlinal area from which erosion has worn away the "Laramie" formation in the central part and exposed the Pierre shale in a broad parklike valley. (See fig. 12.)

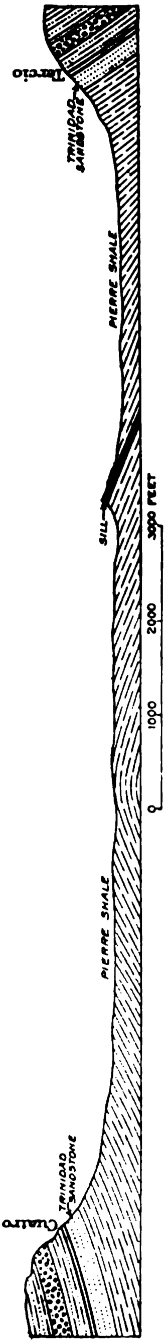

FIGURE 12.—Section between Cuatro and Tercio, Colo.

In this district the strata on the southwestern flanks of the Spanish Peaks syncline have been warped into a subordinate anticline and syncline which extend southward across the state boundary into the Raton coal field. The syncline west of the Tercio embayment has a southward-plunging north-south axis. On the west limb of this fold the strata dip about 25° SE. and on the east limb the dip is about 15° SW. The axis of the Tercio anticline strikes northwest and southeast and the fold is unsymmetrical, the dips being about 55° on the northeast limb and 15° on the southwest limb. Not far northeast of Tercio the dips flatten, and throughout the greater part of the distance between Tercio and Weston the strata lie almost flat, with a northeastward inclination of only a few degrees.

The Pierre shale occupies the surface of the Tercio embayment and to the southwest outcrops in a narrow zone along the base of the western limb of the syncline. Lying immediately above this shale, the Trinidad sandstone forms a locally prominent escarpment above which the coal-bearing rocks outcrop. A bed of conglomeratic sandstone and conglomerate, about 150 feet thick, composed of rounded pebbles of quartz up to 1 inch in diameter, is conspicuously exposed around the rim of the Tercio embayment and occurs about 200 feet above the Trinidad sandstone. This conglomerate in the size and composition of its constituents is in marked contrast to the conglomerate at the base of the Poison Canyon formation 15 miles to the north.

The lower group of coal beds, consisting of two to four beds more than 2 feet thick, occurs between the Trinidad sandstone and the conglomerate and has been considerably exploited throughout the district. These are the only coals that have been prospected, although a bed in the upper group, probably in the same zone as that at Weston (p. 427), is locally exposed.

The Colorado Fuel and Iron Company has expended considerable money in developing the Tercio district, but thus far with poor results. The Colorado and Wyoming Railroad was built up Purgatory Valley to Tercio, where a model mining camp has been constructed; but when visited in 1908 this plant was shut down and, except for some prospecting at Cornell (No. 35), practically no work was being done in the Tercio district.

The following sections show the thickness and stratigraphic occurrence of the coal in this district:

Sections in Tercio district.

Cuatro (No. 34).

Shale.		in.
Coal	2	8
Shale	4	
Coal	2	
Shale	15	
Coal	3	7
Shale	7	
Sandstone	18	
Shale	27	
Coal	4	5
Shale	2-10	
Sandstone, Trinidad.		
Total coal	12	8

Cornell (No. 35).

Sandstone, conglomeratic.	Ft.	in.
Interval	175	
Coal	2	
Bone		7
Coal	2	6
Shale		3
Coal	1	1
Shale	11	
Coal	3	
Shale	4	
Coal	1	
Sandstone, Trinidad.		
Total coal	9	7

At the Tercio mine (No. 33) two beds were mined in which the following measurements were made by J. W. Groves in 1907:

Section of coal beds in Tercio mine.

Shale.	Ft.	In.
Coal	1	2
Bone		2
Coal	2	1
Shale.		
Interval.		
Shale.		
Coal	1	
Bone		2½
Coal	2	
Bone		3
Coal	2	8
Shale		1
Coal		10
Shale.		
Total coal	9	9

INTERIOR DISTRICTS.

MORLEY DISTRICT.

The Morley district includes the area contiguous to the coal outcrops in the vicinity of Morley and Wootton, stations on the Santa Fe Railway, in the southern part of the coal field. In the vicinity of Morley a local fold has brought to the surface the lower coal group, as well as the underlying Trinidad sandstone and Pierre shale. The fold has the form of a narrow elongated dome, from the center of which the beds dip on all sides at an average angle of about 10°. The longer axis of the fold strikes northwest and southeast, and it is probable that the fold is terminated on the north, about two miles from Morley, by a fault striking somewhat north of west, with an upthrow on the south of about 600 feet. The presence of a fault here was suggested by a section made up North Raton Creek between Starkville and Morley, but its existence has not been proved.

The assignment of the Morley coal bed to the lower coal group differs from Hills's conclusions in the Spanish Peaks folio, but there can be no doubt regarding the fact that the coal bed is immediately underlain by typical Trinidad sandstone containing *Halymenites*, and that this in turn is underlain by Pierre shale in which *Inoceramus* occurs. It should be noted that the miners correctly consider the Morley bed to belong to the same group as the Starkville-Engle coal, and also that Stevenson[a] in 1878 announced its correct position.

The coal bed at Morley lies almost on the massive member of the Trinidad sandstone, one measurement showing 2 feet of shale and 10 feet of thin-bedded sandstone and shale between the coal and the main mass of the sandstone. A fine bed of coal is being developed at the new mine at Morley, which apparently is destined to be one of the prominent mines of the field. The bed is reported to average 7 feet of clean coal, though in places it thickens to 8 feet 8 inches, with 4 inches of bone 2 feet below the top.

Other coal beds have not yet been developed in this vicinity and little is known of their occurrence, but at Wootton the upper coal group is exposed, consisting of several varying coal beds ranging from 6 inches to 5 feet in thickness, occurring within a zone of about 100 feet of strata. A number of prospects have been opened on these beds and a new mine, the Red Robin, was being developed in 1908. In the absence of deep drilling and because of the complexity caused by the Morley dome it is difficult to determine in the Trinidad field the exact stratigraphic position of the Wootton coal beds, but sections measured across Raton Pass and correlated with Lee's work in the Raton coal field show that the topmost coal at Wootton is approximately 850 feet above the Trinidad sandstone.

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[a] Stevenson, J. J., U. S. Geog. Surveys W. 100th Mer., vol. 3, Supplement, 1878.

The following section was measured in the Red Robin mine (No. 1) of the Wootton Land and Fuel Company at Wootton:

Section of coal bed in the Red Robin mine.

	Ft.	in.
Shale.		
Coal	3	1
Bone		½
Coal	1	5
Bone		1½
Coal		4
Shale.		
Total coal	4	10

Between 150 and 200 feet above the Wootton coal beds another but much less important set of beds, known as the Tunnel coals, is exposed at the north entrance to the Santa Fe tunnel at Raton Pass, immediately south of the Colorado-New Mexico boundary line. At this place six beds of coal, varying from 1 foot down to a few inches, occur interbedded with sandstone and shale within a zone of 10 feet. On the hillsides above the Wootton coals there are two or three beds belonging to the Tunnel group, ranging from 8 to 20 inches in thickness.

PURGATORY DISTRICT.

The Purgatory district includes the area contiguous to the outcrops of the upper and middle groups of coal beds in the valley of Purgatory River. As now developed, mines have been opened at Primero, Sexto, Frederick, and Quinto. The following section, measured in Purgatory Valley between Sopris and Weston, shows the general sequence of the strata:

Section of rocks in Purgatory Valley between Weston and Sopris.

	Feet.
Coal, Weston.	
Shale, dark	10
Sandstone, gray, massive	50
Sill zone, dark shale, and alternating sills of igneous rock	40
Sandstone, gray, massive, first above camp at Doran's ranch	20
Shale, drab	30
Sandstone, gray, massive	10
Shale, poor coal at top	30
Sandstone, brown, massive	20
Shale and sandstone	50
Coal, Frederick.	
Shale, some thin sandstones	33
Sandstone, gray, massive	25
Shale, some thin sandstones	40
Sandstones, thin bedded, brown, with thin alternating shale	143
Sandstone, very light colored, massive, soft	9
Sill of igneous rock	1
Shale, drab	15
Sandstone, brown, massive	5
Shale, drab	16
Sill of igneous rock	2
Shale, drab	10

	Feet.
Sandstone, brown, massive	4
Shale, dark, with irregular sandy layers	53
Sandstone, gray, massive, false bedded	34
Shale	3
Coal, Sopris.	
	653

The Purgatory district lies in the central part of the syncline, where the strata in general are almost flat. There are local disturbances, however, and the detailed structure is not yet determined. Close correlation of the coal beds also remains to be accomplished; this can best be done by means of a number of diamond-drill holes reaching to the Trinidad sandstone. The section measured along Purgatory River, given above, indicates that the coal bed mined at Frederick is about 400 feet above the Sopris coal, or 590± feet above the Trinidad sandstone.

The variation of the coal is illustrated by the Frederick bed, which was traced from the Frederick mine (No. 24), where it measures 6 feet 6 inches, about 1½ miles southeastward to a point where the bed consists of only 1 foot of bone and coal and from which it could not be further traced. Difficulty was likewise encountered in attempting to trace the bed mined at Primero. At this mine the altitude of the coal is about 350 feet above that at Frederick, but the stratigraphic relation of these two beds has not been determined.

The Primero is well known as one of the largest mines in the Trinidad field. The Frederick mine was but recently (1908) opened, and at Sexto development has not gone beyond the prospecting stage. These properties belong to the Colorado Fuel and Iron Company.

The following measurements show the thickness of these coal beds at the given localities:

Sections of coal beds in the Purgatory district.

Frederick mine (No. 24).

	Ft.	in.
Shale.		
Coal	3	4
Shale		10
Coal	1	11
Shale		5
Coal	1	3
Total coal	6	6

Primero mine (No. 26), room 1, entry A-9.

	Ft.	in.
Shale.		
Coal	1	1
"Sulphur," local		½
Coal	1	4½
Coal, bony		7
Coal		3
"Sulphur," local		1
Coal		4½
"Sulphur"		½
Coal	2	7½
"Sulphur"		1
Coal	1	11
Shale.		
Total coal	8	2½

Sexto (No. 27).

	Ft.	in.
Shale, coaly		5
Coal	1	8
Shale, coaly		7
Coal		6
Shale, coaly		2
Coal	1	6
Shale, floor.		
Total coal	3	8

The coal bed in the Primero mine is reported to vary considerably in thickness, and in places it is cut by dikes and sills which have converted the bed into coke. Good examples of prismatic natural coke are exposed here.

The Quinto mine (No. 32) of the Colorado Fuel and Iron Company, situated half a mile south of Weston, was not in operation in 1908. This mine is on a bed in the upper group which is estimated to be about 900 feet above the Trinidad sandstone. A number of prospect pits have been opened in Wet Canyon at approximately the same horizon. The coal bed in this vicinity ranges from 2 to 6 feet in thickness and contains usually one or two shale partings from a few inches to 2 feet thick. The following section was measured in Wet Canyon a mile and a half north of Weston:

Section of coal bed in Wet Canyon (No. 31.).

	Ft.	in.
Sandstone.		
Shale	1	6
Coal	3	8
Shale		2
Coal	1	6
Sandstone.		
Total coal	5	2

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coal from all parts of the Trinidad field is of a rich black color, with shiny luster and cubical fracture, indicating a good bituminous grade. Corresponding with the differences in chemical composition, however, there are differences in the physical properties of the coal in various parts of the field. In general, coal from the southern part is distinctly different from that in the northern part, though the change from south to north is gradual.

The most important distinction between the coals from the southern and northern parts of the field is that the former makes an excellent coke, whereas, although several attempts have been made, coke of commercial value has not been produced from coal from the northern part of the field. Until lately no physical criterion has been in general use by which a noncoking coal could be distinguished from a coking variety short of an actual test in a beehive oven. But the recent observation of M. A. Pishel,[a] that when ground to a powder coking coals show a pronounced adhesive quality, whereas noncoking coals do not, holds good for the samples from nearly forty mines in the Trinidad field that have been examined. Tests show that specimens of the high-grade coking coal from the southern part of the field adhere distinctly to the pestle when ground in a mortar. The adhesiveness decreases in samples obtained farther north and coals from the north end of the field show practically none under similar conditions. The cause of this "gummy" quality remains to be determined, but the property appears to be an accompaniment of a coking coal.

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[a] A practical test for coking coal: Econ. Geology, June-July, 1908, pp. 265-270.

Coal from the southern part of the field is typically of a deep black color and a brilliant luster and has well-developed cubical fractures. The major system of joints by which the coal is traversed trends at right angles to the strike of the beds and parting planes are especially well developed at intervals of 1 to 4 inches. Less perfect planes of fracture are usually developed at right angles to the major set, so that when mined the coal tends to come out in blocks. So well are these fractures developed in certain areas, as at the Engle and Starkville mines, that powder is not used in mining, picking being sufficient to get out the coal. In the southern part of the field planes of fracture parallel to the bedding of the coal are not so well developed as in the other two directions, and where the coal is broken along the bedding planes it shows numerous small conchoidal fractures with pitted surfaces having a brilliant luster. A brilliant luster is also developed along the principal fracture planes. The coals are further characterized by the development of minute irregular bands of alternating bright and dull coal parallel to the bedding, which otherwise, except by the presence of partings of bone, sandstone, or shale, is ill defined. There are local exceptions to these general characteristics of the coal. At the Primero mine, for example, the usually pronounced joint planes are poorly developed.

Where the coal has come into contact with igneous rocks marked metamorphism has occurred and the coal has been converted to natural coke. The natural coke from the Trinidad field varies with the composition of the coal and with the size and proximity of the intrusive rock. (See p. 435.) In general the coke is deep black and nonlustrous and has a hardness and specific gravity notably greater than unaltered coal. The most pronounced characteristics of the coke are its tendency toward columnar structure and the devolatilization it has undergone as shown by the chemical analyses. (See p. 435.) Polygonal prisms up to 3 inches in diameter are developed with the longer axes at right angles to the intrusive rock. Thus the prisms associated with sills cross the bedding and the prisms caused by dikes are approximately parallel to the bedding planes. In the Trinidad field natural coke is generally considered worthless and doubtless much of it is so, but coke in which ash is not excessive should make a good fuel. Natural coke from the Richmond Basin, Virginia, has been much used.

The typical coal of the northern part of the field is characterized by a less brilliant luster and less well developed joint planes than that in the southern part. At the north the bedding of the coal is more conspicuous and the bands of alternate bright and dull coal are larger and better developed. There is, however, usually one pronounced set of joint planes. Disseminated patches of rosin also occur in the coal of the northern part of the field.

The presence of "niggerheads" is of rather common occurrence in the northern area. These are nodule-like bodies of coal, varying from a few inches to a few feet in diameter, irregularly disseminated in the beds of normal coal. The "niggerheads" are harder than ordinary coal and have a smooth, locally slickensided, lustrous outer surface. The interior is composed of alternating bands of bright and dull coal like the surrounding bed. "Niggerheads" evidently are due to physical strains, but their origin is obscure.

CHEMICAL COMPOSITION.

The analyses given in the table on pages 138–140 show the composition of 25 representative coal samples from different parts of the Trinidad field. Most of the analyses were made from mine samples of fresh, unweathered coal collected by O. J. Bowman and analyzed at the fuel-testing plant of the United States Geological Survey at Pittsburg under the direction of F. M. Stanton.[a] Eight of the analyses indicated on pages 430–432 were made on car samples representing run-of-mine coal taken by John W. Groves[b] and analyzed at the fuel-testing plant of the Geological Survey at Denver. Ultimate and proximate analyses were made of each sample, and the results are expressed in four forms, "as received," "air dried," "dry coal," and "pure coal." Each form is useful for particular purposes, the "air dried" results being best adapted for general use.

The analysis of the sample "as received" shows the composition of the coal, including its moisture content, as received in sealed metal cans at the laboratory, and represents the composition of the coal in the mine. The analysis of the "air dried" sample shows the composition of the coal after a certain amount of its original moisture as mined has escaped. The loss is practically that which escapes on air-drying the coal, but in order to allow for the varying fluctuations of moisture in the air of the laboratory and to have the conditions of analysis uniform, the following procedure is adopted: The powdered coal is exposed in an oven in which a current of air at a temperature between 35° and 40° C. circulates; and the coal is weighed at intervals of three hours until the weight is practically constant. The analysis of "dry coal" shows the composition of the coal on a moisture-free basis. The analysis of "pure coal" shows the composition of the coal on an ash-free and moisture-free basis. All the figures are obtained by recalculating the results of a single analysis.

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[a] Prof. Paper U. S. Geol. Survey No. 48, 1906, pp. 174 et seq.

[b] Washing and coking tests of coal: Bull. U. S. Geol. Survey No. 368, 1909.

Analyses of coal samples from the Trinidad coal field, Colorado.

[F. M. Stanton, chemist in charge.]

LAS ANIMAS COUNTY.

Laboratory No.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
345-D					0.6	As received	2.8	33.1	45.3	18.82	0.62	4.83	64.45	1.17	10.11	6,490	11,682
						Air dried	2.2	33.3	45.6	18.93	.62	4.79	64.84	1.18	9.64	6,529	11,753
						Dry coal		34.1	46.5	19.36	.64	4.65	66.29	1.20	7.86	6,675	12,015
						Pure coal		42.2	57.8		.79	5.77	82.20	1.49	9.75	8,277	14,898
115-D	NW. ¼ NE. ¼	29	33	63	1.2	As received	2.3	29.5	47.8	20.44	.64	4.59	65.00	1.13	8.20	6.508	11,714
						Air dried	1.1	29.8	48.4	20.68	.65	4.52	65.79	1.14	7.22	6,587	11,856
						Dry coal		30.2	48.9	20.91	.65	4.44	66.50	1.16	6.34	6,658	11,984
						Pure coal		38.2	61.8		.82	5.61	84.08	1.47	8.02	8,418	15,152
6312	SW. ¼ SE. ¼	36	33	64	1.1	As received	2.3	30.4	55.6	11.68	.63	5.04	71.91	1.14	9.60	7,327	11,389
						Air dried	1.3	30.7	56.2	11.81	.64	4.97	72.71	1.15	8.72	7,408	13,334
						Dry coal		31.1	56.9	11.96	.65	4.90	73.64	1.17	7.68	7,504	13,507
						Pure coal		35.4	64.6		.74	5.57	83.64	1.33	8.72	8,523	15,341
245-D	NE. ¼ SE. ¼	34	33	64	.9	As received	2.0	28.8	51.4	17.83	.67	4.61	69.46	1.08	6.35	6,930	12,474
						Air dried	1.1	29.1	51.8	17.99	.68	4.55	70.09	1.09	5.60	6,993	12,587
						Dry coal		29.4	52.4	18.18	.68	4.48	70.85	1.10	4.71	7,069	12,749
						Pure coal		35.9	64.1		.83	5.48	86.59	1.34	5.76	8,640	15,343
300-D	NE. ¼ NW. ¼	34	33	64	.3	As received	1.4	28.4	53.4	16.83	.72	4.36	69.99	1.05	7.05	7,070	12,726
						Air dried	1.1	28.5	53.5	16.88	.72	4.35	70.20	1.05	6.80	7,091	12,764
						Dry coal		28.8	54.1	17.08	.73	4.26	71.01	1.07	5.85	7,173	12,912
						Pure coal		34.7	65.3		.88	5.14	85.64	1.29	7.05	8,651	15,572
6310	NW. ¼ SE. ¼	33	33	64	1.0	As received	1.9	28.1	57.0	12.96	.68	4.56	72.15	1.13	8.52	7,285	13,113
						Air dried	.9	28.5	57.5	13.09	.69	4.49	72.88	1.14	7.71	7,359	13,246
						Dry coal		28.7	58.1	13.21	.69	4.43	73.54	1.15	6.98	7,426	13,367
						Pure coal		33.1	66.9		.80	5.10	84.73	1.33	8.04	8,556	15,501
6321	SE. ¼	25	33	65	1.9	As received	2.7	25.8	57.3	14.18	.61	4.63	71.08	1.09	8.41	7,139	12,850
						Air dried	.8	26.3	58.4	14.45	.62	4.51	72.46	1.11	6.85	7,277	13,099
						Dry coal		26.5	58.9	14.57	.63	4.45	73.03	1.12	6.20	7,335	13,203
						Pure coal		31.1	68.9		.74	5.21	85.48	1.31	7.26	8,586	15,455

6370	NE. ¼	26	33	66	1.5	As received	2.3	29.8	58.7	9.16	.50	5.22	74.24	1.08	9.80	7,655	13,781
						Air dried	.8	30.3	59.6	9.30	.51	5.13	75.37	1.10	8.59	7,773	13,991
						Dry coal	....	30.5	60.1	9.37	.51	5.09	75.97	1.11	7.95	7,834	14,101
						Pure coal	....	33.7	66.3	....	.56	5.62	83.83	1.22	8.77	8,644	15,559
116-D	....	......	......	......	1.7	As received	2.9	29.9	48.1	19.13	.77	4.61	65.28	1.06	9.15	6,511	11,720
						Air dried	1.2	30.4	48.9	19.46	.78	4.50	66.41	1.08	7.77	6,624	11,923
						Dry coal	....	30.8	49.5	19.69	.79	4.42	67.21	1.09	6.80	6,703	12,066
						Pure coal	....	38.4	61.6	....	.98	5.50	83.69	1.36	8.47	8,346	15,024
117-D	....	......	......	......	1.5	As received	2.7	31.2	50.1	16.03	.68	4.86	68.37	.99	9.07	6,870	12,366
						Air dried	1.2	31.7	50.8	16.27	.69	4.76	69.41	1.01	7.86	6,975	12,554
						Dry coal	....	32.0	51.5	16.47	.69	4.69	70.24	1.02	6.89	7,058	12,704
						Pure coal	....	38.4	61.6	....	.83	5.61	84.09	1.22	8.25	8,450	15,212
6455	....	18	32	68	2.0	As received	3.2	30.6	58.8	7.41	.67	4.76	75.74	1.10	10.32	7,540	13,572
						Air dried	1.2	31.2	60.0	7.56	.68	4.63	77.29	1.12	8.72	7,694	13,849
						Dry coal	....	31.6	60.7	7.65	.69	4.55	78.19	1.14	7.78	7,784	14,011
						Pure coal	....	34.2	65.8	....	.75	4.93	84.66	1.23	8.43	8,429	15,172
6458	NE. ¼ SW. ¼	24	32	64	1.7	As received	3.1	28.0	50.6	18.34	.63	4.94	65.91	.93	9.25	6,594	11,869
						Air dried	1.3	28.5	51.5	18.66	.64	4.83	67.05	.95	7.87	6,708	12,074
						Dry coal	....	28.9	52.2	18.92	.65	4.74	67.98	.96	6.75	6,801	12,242
						Pure coal	....	35.6	64.4	....	.80	5.85	83.84	1.18	8.33	8,388	15,098
6456	NE. ¼ NE. ¼	36	31	65	2.3	As received	3.3	32.6	53.7	10.39	.74	5.30	72.61	1.24	9.72	7,329	13,192
						Air dried	1.1	33.3	55.0	10.64	.76	5.16	74.32	1.27	7.85	7,402	13,504
						Dry coal	....	33.7	55.6	10.75	.76	5.10	75.09	1.28	7.02	7,580	13,644
						Pure coal	....	37.7	62.3	....	.85	5.71	84.13	1.43	7.88	8,493	15,287
152-D	W. ½	15	31	65	1.0	As received	3.2	34.0	51.2	11.57	.58	5.23	71.44	.99	10.19	7,123	12.821
						Air dried	2.2	34.3	51.8	11.69	.59	5.17	72.16	1.00	9.39	7,195	12,951
						Dry coal	....	35.1	52.9	11.95	.60	5.04	73.79	1.02	7.60	7,358	13,243
						Pure coal	....	39.9	60.1	....	.68	5.73	83.80	1.16	8.63	8,357	15,040
6528	NW. ¼	34	30	65	.7	As received	2.2	34.8	54.8	8.24	.72	4.97	75.11	1.21	9.75	7,453	13,415
						Air dried	1.4	35.1	55.2	8.29	.73	4.93	75.64	1.22	9.19	7,506	13,511
						Dry coal	....	35.6	56.0	8.42	.74	4.83	76.76	1.24	8.01	7,617	13,711
						Pure coal	....	38.9	61.1	....	.81	5.27	83.81	1.35	8.76	8,317	14,971
6536	NE. ¼	20	30	65	1.1	As received	2.4	35.1	56.4	6.06	.42	5.30	76.93	1.19	10.10	7,530	13,554
						Air dried	1.4	35.5	57.0	6.13	.42	5.24	77.79	1.20	9.22	7,614	13,705
						Dry coal	....	36.0	57.8	6.21	.43	5.15	78.84	1.22	8.15	7,717	13,891
						Pure coal	....	38.4	61.6	....	.46	5.49	84.06	1.30	8.69	8,228	14,810
6533	NW. ¼ NE. ¼	9	30	65	2.3	As received	3.7	33.7	52.1	10.48	.64	5.30	70.93	1.19	11.46	7,025	12,645
						Air dried	1.4	34.5	53.4	10.73	.66	5.16	72.60	1.22	9.63	7,190	12,742
						Dry coal	....	35.0	54.1	10.88	.66	5.08	73.63	1.24	8.51	7,293	13,127
						Pure coal	....	39.2	60.8	....	.74	5.70	82.62	1.39	9.55	8,183	14,729
6530	SE. ¼ NW. ¼	5	30	65	1.4	As received	3.0	34.5	53.5	8.98	.35	5.08	71.98	1.31	12.30	7,185	12,933
						Air dried	1.7	34.9	54.3	9.11	.36	4.99	73.00	1.33	11.21	7,287	13,117
						Dry coal	....	35.5	55.2	9.26	.36	4.89	74.24	1.35	9.90	7,411	13,340
						Pure coal	....	39.1	60.9	....	.40	5.39	81.81	1.49	10.91	8,167	14,701

Analyses of coal samples from the Trinidad coal field, Colorado—Continued.

HUERFANO COUNTY.

Laboratory No.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. W.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	B. t. u.
6532	NE. ¼	30	29	65	2.8	As received	4.1	34.0	50.1	11.84	0.67	5.09	70.34	1.09	10.97	6,887	12,397
						Air dried	1.3	35.0	51.5	12.18	.69	4.92	72.37	1.12	8.72	7,085	12,753
						Dry coal	....	35.5	52.2	12.34	.70	4.84	73.34	1.14	7.64	7,180	12,924
						Pure coal	....	40.4	59.6	....	.80	5.52	83.67	1.30	8.71	8,191	14,744
6540	NE. ¼	24	29	66	1.9	As received	3.4	35.6	51.4	9.64	.75	5.24	70.96	1.23	12.18	7,108	12,794
						Air dried	1.5	36.3	52.4	9.83	.76	5.13	72.33	1.25	10.70	7,246	13,043
						Dry coal	....	36.9	53.1	9.98	.78	5.03	73.44	1.27	9.50	7,357	13,244
						Pure coal	....	40.9	59.1	....	.87	5.59	81.58	1.41	10.55	8,173	14,711
6541	NE. ¼	24	29	66	2.2	As received	3.6	34.5	50.3	11.58	.57	5.32	69.84	1.05	11.64	6,886	12,395
						Air dried	1.5	35.3	51.4	11.84	.58	5.19	71.41	1.07	9.91	7,041	12,674
						Dry coal	....	35.8	52.2	12.01	.59	5.10	72.46	1.09	8.75	7,144	12,860
						Pure coal	....	40.7	59.3	....	.67	5.80	82.35	1.24	9.94	8,119	14,614
6547	NE. ¼ NW. ¼	17	28	66	4.4	As received	6.9	34.9	49.7	8.46	.53	5.45	69.15	1.02	15.39	6,710	12,078
						Air dried	2.6	36.5	52.0	8.85	.55	5.19	72.33	1.07	12.01	7,019	12,634
						Dry coal	....	37.5	53.4	9.09	.57	5.03	74.27	1.10	9.94	7,207	12,973
						Pure coal	....	41.3	58.7	....	.63	5.53	81.69	1.21	10.94	7,927	14.269
240-D	NW. ¼	23	27	67	1.8	As received	6.0	35.5	39.6	18.86	1.04	4.92	58.30	.98	15.90	5,862	10,552
						Air dried	4.3	36.1	40.4	19.21	1.06	4.80	59.37	1.00	14.56	5,969	10,744
						Dry coal	....	37.7	42.2	20.08	1.11	4.52	62.05	1.04	11.20	6,239	11,232
						Pure coal	....	47.2	52.8	....	1.39	5.66	77.64	1.30	14.01	7,807	14,054
6551	SW. ¼ NW. ¼	9	27	67	7.0	As received	10.2	34.3	43.8	11.65	.58	5.63	61.75	1.00	19.39	6,035	10,863
						Air dried	3.4	36.9	47.2	12.53	.62	5.22	66.40	1.07	14.16	6,489	11,680
						Dry coal	....	38.2	48.8	12.97	.66	5.01	68.76	1.11	11.49	6,721	12,098
						Pure coal	....	43.9	56.1	....	.76	5.76	79.01	1.28	13.19	7,722	13,900
6608	NW. ¼ SW. ¼	10	29	69	3.4	As received	6.4	35.2	47.5	10.87	.56	5.30	65.66	1.01	16.60	6,472	11,650
						Air dried	3.2	36.4	49.1	11.25	.58	5.09	67.97	1.05	14.06	6,700	12,060
						Dry coal	....	37.6	50.8	11.62	.60	4.90	70.20	1.08	11.60	6,920	12,456
						Pure coal	....	42.6	57.4	....	.68	5.54	79.43	1.22	13.13	7,830	14,094

Data concerning samples of coal from Trinidad field represented by analyses.

LAS ANIMAS COUNTY.

Laboratory No.	Nearest town.	Name of mine.	Location in mine.	Section of coal bed represented by sample.	Kind of coal and condition of sample.
345-D	Wootton	Red Robin			Run-of-mine.
115-D	Engleville	Engle			Do.
6312	Starkville	Starkville	Room 6, entry G 4.	See page 397	Fresh, unweathered.
245-D	do	Francisco			Run-of-mine.
300-D	Sopris	Piedmont			Do.
6310	do	Sopris	Room 3, entry 17 W	See page 398	Fresh, unweathered.
6321	Cokedale	Cokedale	Room 26, entry 4 W	See page 400	Do.
6370	Primero	Primero	Room 1, entry A 9.	See page 426	Do.
116-D	Tercio	Tercio (bed No. 2).			Run-of-mine.
117-D	do	Tercio (bed No. 3).			Do.
6455	Stonewall	Clark's prospect	100 feet from opening.	4 ft. 11 in	Slightly weathered.
6458	Trinidad	Bowen	Room 11, entry 2 N 6 E.	See page 401	Fresh, unweathered.
6456	Berwind	Berwind No. 3	Face of second south off entry 14 E.	*Ft. in.* Coal........ 4 Bone, discarded.... 1 2 Coal........ 4 4	Do.
152-D	Delagua	Delagua No. 2			Run-of-mine.
6528	Aguilar	Peerless annex	Room 1, north entry.	4 feet	Fresh, unweathered.
6536	do	Las Animas No. 4.	Breast of workings.	4 feet	Do.
6533	Rugby	Rapson	Face of entry 3 S.	See page 406	Do.
6530	Primrose	Primrose	Room 3, entry 1½ N	See page 409	Do.
HUERFANO COUNTY.					
6532	Rouse	Rouse	Face of entry 8 E.	See page 412	Fresh, unweathered.
6540	Pryor	Pryor lowest bed.	Face of entry 3 N.	*Ft. in.* Coal, bony, discarded. 3 Coal........ 1 6½ Coal, bony, discarded. 1 Coal........ 2 5 Coal, bony, discarded. 6	Do.
6541	do	Pryor middle bed.	Entry 2 S., 150 feet from bottom of slope.	Coal, bony, discarded. 9 Coal........ 5 Shale, discarded.... 2½ Coal........ 4 3	Do.
6547	Walsenburg.	Robinson	Eighth cross entry off 8 N.	See page 415	Do.
240-D	Shumway	Piñon No. 3			Nut coal.
6551	Strong	Sunnyside	Face of main slope.	See page 417	Fresh, unweathered.
6608	La Veta	Oakdale	Face of entry 3 S.	7 ft. 4 in	Do.

The table of analyses shows the following range and average composition of the samples from Las Animas and Huerfano counties on an air-dried basis:

Range and average composition (air-dried basis) of coal samples from Trinidad field.

	Las Animas County (18 samples).		Huerfano County (7 samples).	
	Range.	Average.	Range.	Average.
Moisture	0.8 - 2.2	1.30	1.3 - 4.3	2.54
Volatile matter	26.3 -35.5	31.44	34.5 -36.9	36.07
Fixed carbon	45.6 -60.0	53.83	40.4 -52.4	49.14
Ash	6.13-20.68	13.43	8.85-19.21	12.24
Sulphur	.30- .78	.64	.55- 1.06	.69
Hydrogen	4.35- 5.24	4.82	4.80- 5.22	5.08
Carbon	64.84-77.79	73.89	59.37-72.37	68.88
Nitrogen	.95- 1.33	1.13	1.00- 1.25	1.09
Oxygen	5.60-11.21	8.32	8.72-14.56	12.02
British thermal units	11,753-13,991	12,920	10,744-13,043	12,227

These figures illustrate the well-known fact that the general product of the Trinidad field is a high-grade bituminous coal. It is comparable with the better coals of the Mississippi Valley and with many coals of the Appalachian region, and is distinctly superior to the product of most of the Rocky Mountain fields. The figures also show that the coal from Las Animas County is superior to that from Huerfano County. The coal from the northern part of the field is well adapted to domestic and steaming purposes, while that from the southern part makes a high-grade coke. It is the coking quality of the coal that gives the area under consideration special importance, for the Raton Mesa coal region is the chief area of coking coal west of Mississippi River.

The sulphur and moisture content of the coal throughout the field is low, sulphur in the air-dried samples ranging from 0.36 to 1.06 per cent. Moisture in the coal from two mines in the southern part of the field is less than 1 per cent, but toward the north the moisture content increases and in one mine in Huerfano County is more than 4 per cent. Ash, on the other hand, is generally rather high, averaging almost 13 per cent.

The ultimate analysis of pure coal, especially the percentage of carbon, affords data for judging the degree of metamorphism or devolatilization which the coal has undergone in its transformation from the original vegetable constituent matter. It is well known that in the process of coal making the carbon and hydrogen increases at the expense of oxygen and nitrogen, carbon ranging from about 55 per cent in peat to 95 per cent in anthracite. Inspection of the analyses of pure coal from the Trinidad field emphasizes the general high-grade character of the fuel, and the incomplete data at hand[a] indicate that the greatest metamorphism of the coal has occurred in the area adjacent to Purgatory River, southwest of Trinidad, where three tests show that the coal contains more than 85 per cent of carbon. The analyses show a general decrease of regional metamorphism from the southern part of the field northward, the total carbon ranging from 86 per cent in the south to 77 per cent in the north. But there are not enough analyses from all parts of the field, especially from the little-known interior portion, on which to base a more precise statement concerning the varying metamorphism.

These regional differences in composition are independent of local contact metamorphism by igneous rocks, of which there is abundant evidence in the Trinidad field. The metamorphosing effect on coal of both sills and dikes, however, appears to be local. Sills are much more destructive than dikes, for they affect a greater body of coal. In most places where sills are in contact with coal the bed is entirely altered to natural coke and rendered commercially worthless. Dikes, on the other hand, affect a relatively small body of coal. A number of observations in mines show that generally the coal in the vicinity of a dike is coked only for a distance on each side about equal to the width of the dike. For instance, samples were collected for analysis in the eighth east entry of the new Rouse mine, in the vicinity of a dike, to determine the extent of its metamorphosing influence. There a dike 14 inches wide cuts across the coal bed, which is 63 inches thick. The coal has been coked on both sides of the dike for a distance of about 18 inches and prismatic structure is well developed in the coke perpendicular to the dike. The following analyses show that the coal has been distinctly altered by the dike and that the change from coke to coal is rather abrupt:

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[a] The analyses represent coal chiefly from the margin of the field, samples from the interior being not available.

Ultimate analyses of natural coke and coal from Rouse mine.

[Moisture and ash free basis.]

	Natural coke 1 foot from dike.	Coal 1 foot from natural coke, 2½ feet from dike.	Coal 15 feet from dike.
Hydrogen	2.82	5.70	5.60
Carbon	91.41	81.98	81.51
Nitrogen	1.21	1.32	1.42
Oxygen	3.85	10.27	10.72
Sulphur	.71	.73	.75
	100.00	100.00	100.00

The following analyses give the composition of samples of natural coke and of typical coal from the Primero mine and from the Rouse mine:

Proximate analyses (dry-coal basis) of natural coke and coal, Primero and Rouse mines.

	Volatile matter.	Fixed carbon.	Ash.
Primero mine:			
Natural coke	8.3	80.9	10.8
Typical coal	30.5	60.1	9.4
Rouse mine:			
Natural coke	6,7	71.0	22.0
Typical coal	35.5	52.2	12.3

It is an interesting fact that although igneous rocks in the Trinidad field have coked the coal with which they have come into contact, anthracite coal, so far as the writer is aware, has not been found. It is probable, however, that in the deeply covered area contiguous to the great intrusive masses that form the Spanish Peaks profound changes of the coal have occurred.

The fact that this area has been the seat of great igneous intrusions suggests that the general quality of the coal has been materially affected by the igneous rocks. Yet comparison of analyses in connection with the distance of the samples from the center of intrusion—the Spanish Peaks—and consideration of the known limited metamorphosing effect of dikes cast doubt on the supposition of a direct connection of the igneous rocks with the general character of the coal. It appears more probable that regional influences, with which perhaps the intrusions of the igneous rocks were connected, caused the varied metamorphism of the coals; but the nature of the forces involved is a matter of speculation.

DEVELOPMENT.

HISTORY.

The presence of coal in the Trinidad field has been known since the early days of settlement, but the development of the field is of relatively recent date. Coal mining as an industry in Colorado is reported to have begun in 1864, when a production of only 500 tons was recorded. Statistics for the southern part of the State do not go further back than 1873, when the production of Las Animas County was grouped with that of Fremont County, the total for the two in that year being only 12,187 tons.

The development of the Trinidad field has been rapid, because of the superior quality of the coal. The earliest mines operated on a large scale were those at Starkville and Engleville, in the vicinity of Trinidad, and the Walsen, Robinson, and Cameron mines, near Walsenburg. For a number of years these were practically the only producers. During the period of general prosperity between 1887 and 1893 a number of new mines were opened along the eastern outcrop of the coal, including the Sopris, Berwind, Rouse, Hastings, Santa Clara, Forbes Canyon, Pictou, Peerless, and Brodhead. Branch lines from the Colorado and Southern and the Denver and Rio Grande railroads were built to these and other workings. Few new mines were started between 1893 and 1898, but the era of prosperity which terminated in 1907 and was checked only by the strike of 1903-4 witnessed a great development of the field. The production of the old mines was greatly increased and many new ones were opened. Purgatory Valley was made accessible by the construction of the Colorado and Wyoming Railroad and mines were opened at Primero, Tercio, and elsewhere. The northern part of the field was also actively developed by the extension of the Walsenburg-Pictou branch of the Denver and Rio Grande Railroad to Strong and Tioga, and the Piñon, Sunnyside, and other mines in that vicinity were opened.

The eastern outcrop of the coal has been well exploited and at present several score mines, whose locations are shown on the map (Pl. XX), are in operation. The western outcrop, however, because of its relative inaccessibility except at the north in the vicinity of La Veta and at the south in the vicinity of Tercio, is undeveloped. The interior of the basin, which constitutes the great reserve of the field, is almost untouched except for the few mines in the Morley and Purgatory districts. Great quantities of coal are yet to be obtained from mines located along the outcrop, but the future tendency will be to develop more and more the interior of the field by shafts, at first not far distant from the outcrop but later near the center of the basin.

MINING.

GENERAL CONDITIONS.

Conditions of mining in the Trinidad coal field are generally favorable. The climate permits unhampered outdoor work throughout the year. The water supply in a large part of the field is ample, timber is available near by, and the coal beds are in such a position as to be readily accessible and are easily worked.

The accessibility of the coal beds has been an important factor in determining the location of the principal mines, to which branch lines have been constructed from the main railroads. In some places where the coal outcrops high up in cliffs—for example, at the Bowen mine—the workings are reached by gravity planes, the main plant being situated in the adjacent lowlands, but most of the mines are located in good sites for camps. With few exceptions the mining companies have not only taken pains to construct economically efficient plants equipped with modern appliances, but have laid out the town sites in an attractive manner, with attention to general appearances and to sanitary conditions. In a number of camps the buildings are constructed of concrete and the hygienic conditions are admirable. The camps are generally equipped with waterworks, electric lights, etc., and are provided with churches, schools, and clubhouses.

WATER SUPPLY.

The Trinidad field is situated in the semiarid region, where the water supply is always an important factor, but the field lies near the base of the Sangre de Cristo Range and is watered by two perennial streams, Purgatory and Cuchara rivers; the intermittent streams which head in the vicinity of the Spanish Peaks, particularly Apishapa, Santa Clara, and Bear creeks, carry smaller amounts of water. The lofty Raton Mesa is also well watered, but the greater part of the field is destitute of surface water, being drained by arroyos that are generally dry except after torrential summer storms. The water-supply problem must therefore be solved in developing the interior part of the field. Much surface water can be saved by the construction of reservoirs, and it is probable that over a large part of the basin wells sunk to the Trinidad sandstone will strike water under pressure.

The camps adjacent to Purgatory Valley obtain their water supply from the river. In the western part of the field, near the headwaters of this stream, an abundance of good clear water is available, but farther downstream the supply becomes less in quantity and poorer in quality. A pumping plant at Segundo provides water for the coke ovens and settlement there and also furnishes water to the camp at Primero, about 2 miles north of the river. The water for the mine at Sopris also has to be pumped a considerable distance. At Cokedale water for the ovens is taken from the river and a better supply for domestic purposes is obtained by the construction of a subsurface dam across Reilly Canyon. By this contrivance the underflow of the creek is intercepted and pumped to a reservoir, from which it is distributed to the camp. In the southern part of the field the mines are usually dry and sprinkling is necessary to keep down the dust. The camps along the cliffs north of Trinidad are in general poorly supplied with water and for several of them water is hauled by tank cars from Trinidad, which has an excellent supply derived from the base of the mountains about 30 miles west of the city.

Farther north the large mines and coking plants in Road Canyon and in Canyon de Agua receive their supply by a pipe line from the abandoned Peerless mine, west of Aguilar. Between Apishapa Creek and Cuchara River there is an abundance of water in many of the mines, including the Peerless, Brodhead, Green Canyon, Rouse, Pryor, and Hezron. This water apparently has its source in the Trinidad sandstone, and in several places seems to come up along fault planes. (See p. 413.) In some of these mines powerful pumps have been installed. North of Walsenburg comparatively little trouble is caused by water and the supply from the mines is used in the camps, which otherwise would be poorly provided. In the new workings at the extreme north end of the field the water supply at present is insufficient and in some places water is hauled several miles from Huerfano River.

METHODS OF MINING.

The occurrence of the coal in an unsymmetrical basin necessitates different mining methods to meet the varied conditions. Along the eastern outcrop of the coal, where most of the mines are situated, the dip of the rocks is generally at a low angle to the southwest, the inclination rarely exceeding 10° and in many places being less than 3°. In the central part of the basin, where upper beds are worked by mines on the outcrop, the coal beds lie practically flat; and along the western outcrop of the coal the few mines that have been opened encounter steep dips, ranging from 40° to 90°.

There are no deep mines in the area here considered and only three shafts have been sunk, the deepest of which is 360 feet. The cover in most of the mines is not more than 300 or 400 feet, the greatest depth beneath the surface in any of the workings being about 1,100 feet at the southeast end of the Starkville mine. In the area contiguous to Walsenburg three beds of coal of workable thickness occur within a vertical range of 100 feet and several of the mines in that vicinity work all three beds. (See fig. 9.)

The roof in the mines varies. In a number of places it is a firm sandstone, but in others the roof is a weak shale, which causes trouble. A sandy shale is the most common material and in general makes a satisfactory roof. The floor is generally shale and gives little trouble except in places where the shale is so weak that in drawing pillars "squeezes" are likely to occur unless special precautions are taken. Variations in the thickness of the coal bed cause local "rolls," which in places require brushing of the roof to maintain proper grades.

Locally the workings are very extensive, for some of the mines have been in operation more than thirty years. In the Engle and Starkville mines, which are the oldest in the field, the workings, as already stated, occupy an area of about 3½ square miles. These two mines, the entrances of which are 2½ miles apart in an air line, are connected underground. From such dimensions the mines grade down in size to mere prospects. In 1907 there were 22 mines in the Trinidad field with a yearly output of more than 100,000 tons each.

The usual system of working is that of rooms and pillars with double entries. The entries are about 10 feet wide. The rooms vary considerably in size, but probably average 15 by 250 feet. The pillars between rooms are about 25 feet wide. The coal is generally shot from the solid, but in places it is undercut by pick and in a few mines, where cubical cleavage in the coal is well developed, as at Engleville and Starkville, shooting is not necessary and the coal is mined by pick only. Mining machines are not generally used, although in the northern part of the field they have been introduced to a slight extent. Along the western margin of the basin, where dips are steep, different methods are employed. At Tercio, where South Fork of Purgatory River has cut through the ridge, which is underlain by coal-bearing rocks that dip about 45° NE., an entry is driven on the outcrop parallel to the strike, with an air course about 20 feet above. The rooms, 25 feet wide, are driven up the rise, with 20-foot pillars. At the Occidental mine, west of La Veta, the coal, which is practically vertical, is reached by a tunnel. The entrance to the mine is located in a valley in the Pierre shale west of the coal measures, and the tunnel, about 300 feet long, penetrates the Trinidad sandstone before reaching the coal. The coal is worked by the stall-and-pillar system, with pillars about 15 feet thick. (See fig. 11.)

The methods of haulage vary with conditions. In most of the large mines where the dip is not too great the coal is hauled by means of electric motors using the trolley system. Rope haulage is employed on the steeper slopes. Mules are used chiefly for gathering the mine cars from the rooms to the main haulage ways.

Ventilation in connection with the double-entry system of mining is usually accomplished by exhaust fans operated either by steam or by electricity.

Gas, in greater or less quantity, is present in all the mines. In many it causes little or no trouble, but in others disastrous explosions have occurred.[a] Much of the danger seems to be in dust explosions which are started by the ignition of gas. Although in some of the more gaseous mines the use of safety lamps is obligatory this precaution is not sufficient, and where the workings are naturally dry care should be taken to lay the dust by an efficient system of sprinkling. It has been found that sprinkling the floors only is inadequate; the sides and roof also should be kept moist.

PREPARATION OF COAL FOR THE MARKET.

The "dirty" condition of the coal in this region generally necessitates some sorting before the product is marketable. Most of this work is done in the mines, the miners being required to discard "bony coal and impurities."

In the Trinidad district, where the greater part of the coal is coked, all that is so used is first washed. At some plants only the slack is made into coke, but where the entire output is coked the lump coal is crushed before washing. Results are different at the different plants, but the general conditions are indicated by the washing tests of coal from this field made at the government fuel-testing plant at Denver in 1907.[b] The following table shows the results of a number of tests:

Results of washing tests of coal from Trinidad field.

[Moisture-free basis.]

Source of coal tested.	Raw coal.		Washed coal.				Refuse.		
	Tons used in test.	Per cent of ash.	Tons obtained.	Per cent of raw coal used.	Per cent of ash.	Per cent of ash reduction.	Tons resulting.	Per cent of raw coal used.	Per cent of ash.
Engleville	9.30	20.91	6.60	71	13.17	37	2.70	29	36.59
Tercio	12.25	19.69	10.65	87	16.23	18	1.60	13	46.44
Delagua	6.64	11.95	6.00	90	9.74	19	.64	10	44.09
Shumway	5.86	20.08	4.80	82	13.32	34	1.06	18	33.33
Sopris	11.44	18.18	8.91	78	12.31	32	2.53	22	37.84
Hastings	17.04	19.62	13.67	80	12.05	39	3.37	20	44.58
Wootton	8.82	19.36	6.90	79	13.41	31	1.92	21	38.86

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[a] See state coal-mine inspector's reports.

[b] Washing and coking tests of coal at Denver, Colo.: Bull. U. S. Geol. Survey No. 368, 1909, pp. 24-34.

The table shows that the percentage of ash in raw coal may be reduced about one-third by washing, and that the refuse is roughly 20 per cent of the coal used. About 60 per cent of the refuse is combustible matter.

At mines where the coal is not coked, principally in the northern part of the field, the coal is frequently hand sorted before shipping, and at Shumway it is proposed to install a washing plant to insure a better grade of domestic fuel.

The coal is usually put on the market in four grades—run-of-mine, lump, nut, and slack. The entire product of only a few mines is disposed of as run-of-mine; generally the coal is sized, both shaking and stationary screens being used. In this region there are no standard sizes for the several grades, and at each mine the practice is different. The most common sizes are as follows: Lump coal is that which passes over openings that vary in size between 1½ and 3 inches, nut coal passes over openings between three-fourths inch and 1¼ inches, and slack is that which passes through one-half to 1-inch openings.

COKE.

In 1907 a total of 937,451 tons of coke was produced in the Trinidad coal field at the following ten plants, all in Las Animas County:

Coke plants in Trinidad coal field.

Plant.	Number of ovens.	Owner.
Segundo	800	Colorado Fuel and Iron Company.
Tercio	600	Do.
Tabasco	302	Do.
Sopris	272	Do.
Elmoro	235	Do.
Starkville	190	Do.
Hastings	189	Victor Fuel Company.
Delagua	160	Do.
Gray Creek	100	Do.
Cokedale	300	Carbon Coal and Coke Company.

In November, 1907, the Elmoro washeries were totally destroyed by fire and those at Sopris suffered a similar fate in March, 1908. These plants consequently were not in use when the field was visited in 1908. The Tercio plant was also idle, and the coke ovens at Gray Creek were not in use; so that only six coking plants were then in operation, and the output of coke was considerably less than that of the previous year. In the manufacture of the 1907 output of coke, 1,547,848 tons of coal is reported to have been employed, making the ratio of coal used to coke produced approximately 61 per cent. The coal used in coke making in 1907 amounted to about 32 per cent of the total coal production of Las Animas County.

The large quantity of impurities contained in the coal makes it necessary that all of the product used for coke making be first washed. A considerable part of the coal used is slack, although a large part is run-of-mine. Ordinary 13-foot beehive ovens are in use throughout the field. At some plants mechanical coke pullers and other modern improvements are used, but in general a high grade of efficiency is not maintained. There are no fireproof washeries and no retort or underflue ovens in the field, so that all of the by-products and enormous quantities of heat are wasted. Conditions at Dawson, in the Raton field, where all of the heat used for the boiler plant is derived from the coke ovens and where there is an unusually efficient plant, might with advantage be introduced in the Colorado portion of the region.

The coke is a high-grade product which is used both in copper smelting and in the manufacture of iron and steel. The following tabulated statement of results at the government fuel-testing plant at Denver in 1907 and 1908[a] indicates general conditions. For further details Bulletin 368 and the papers noted on pages 379–380 should be consulted.

Coking tests of coals from the Trinidad field.

		Test 195 Engleville.	Test 221, Sopris.	Test 205, Tercio.	Test 217, Hastings.	Test 203. Delagua.
Date		12,2,07	2,12,08	1,4,08	2,3,08	12,30,07
Duration	hours	64	44	37	38	54
Size:[b]						
As shipped		r. o. m.	r. o. m.	r. o. m.	sl.	r. o. m.
As used		½ in.	w., n. c.	w., f. c.	w., f. c.	w., f. c.
Coal charged:						
Wet	pounds	13,310	12,000	10,970	9,940	12,970
Dry	do	12,868	11,423	10,606	9,494	12,044
Coke produced:						
Wet	do	9,000	8,367	7,380	6,450	7,660
	per cent	67.62	69.73	67.27	64.89	58.98
Dry	pounds	8,932	8,347	7,345	6,413	7,596
	per cent	69.41	73.07	69.25	67.55	63.07
Breeze produced:						
Wet	pounds	528	279	337	215	585
	per cent	3.97	2.32	3.07	2.16	4.51
Dry	pounds	524	278	335	214	581
	per cent	4.07	2.43	3.16	2.25	4.82
Total yield:						
Wet	do	71.59	72.05	70.34	67.05	63.49
Dry	do	73.48	75.50	72.41	69.80	67.89
Physical properties of coke:						
Specific gravity—						
Apparent		1.05	1.08	1.00	1.04	.98
Real		1.92	1.93	1.93	1.91	1.86
Volume—						
Coke	per cent	55.00	56.00	52.00	54.00	53.00
Cells	do	45.00	44.00	48.00	46.00	47.00
Weight per cubic foot—						
Wet	pounds	93.08	94.64	92.01	93.15	89.99
Dry	do	65.00	67.21	62.06	64.47	60.69
6-foot drop test over 2-inch mesh—						
1	per cent	93.00	98.00	93.00	98.00	94.50
2	do	86.00	94.50	90.50	95.00	90.00
3	do	81.00	93.00	86.00	94.00	86.50
4	do	76.50	90.00	83.50	90.50	81.00
5	do	86.00	89.00	88.50	92.00	84.50

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[a] Washing and coking tests of coal at Denver, Colo.: Bull. U. S. Geol. Survey, No. 368, 1909, pp. 34–63.

[b] r. o. m., Run-of-mine; sl., slack; w., washed; n. c., not crushed; f. c., finely crushed.

Remarks.—Test 195: Light-gray color with some little silvery coloration. Breakage good; long, large pieces. Cell structure, a little large. Metallic ring.

Test 221: Light-gray and silvery color; heavy deposit of carbon, probably cause of increased yield. Breakage good; long, large pieces. Metallic ring. Very heavy, good coke. Cells not so well closed as in coke from finely crushed coal.

Test 205: Light gray and silvery; large deposit of carbon. Cell structure good. Breakage good; long, large pieces. Metallic ring. Good, heavy coke.

Test 217: Light gray and silvery. Cell structure good. Breakage good. Good, metallic ring. Good, heavy coke. Charge ashed down about one-half inch over entire surface.

Test 203: Fingered. Dark coloration, but large deposit carbon. Cell structure small, not dense. Somewhat brittle and soft. Metallic ring. Good, heavy coke.

Chemical analyses of coal and coke in above tests.

Test No.	Laboratory No.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Phosphorus.
195	124-D	Coal	Wet	3.32	31.99	51.96	12.73	0.61	
			Dry		33.08	53.75	13.17	.63	
	130-D	Coke	Wet	.76	1.23	77.48	20.53	.44	0.0235
			Dry		1.24	78.07	20.69	.44	
221	301-D	Coal	Wet	4.81	29.86	52.47	12.86	.63	
			Dry		31.38	55.10	13.52	.66	
	335-D	Coke	Wet	.24	.49	82.49	16.78	.81	.0140
			Dry		.49	82.68	16.83	.61	
205	207-D	Coal	Wet	3.32	31.08	49.90	15.70	.72	
			Dry		32.15	51.60	16.25	.75	
	209-D	Coke	Wet	.47	.46	77.10	21.97	.66	.0217
			Dry		.46	77.46	22.08	.66	
217	269-D	Coal	Wet	4.49	33.06	50.35	12.10	.65	
			Dry		34.61	52.72	12.67	.68	
	286-D	Coke	Wet	.57	.66	81.59	17.18	.57	.0077
			Dry		.66	72.06	17.28	.57	
203	204-D	Coal	Wet	7.14	34.09	49.96	8.81	.50	
			Dry		36.72	53.79	9.49	.54	
	206-D	Coke	Wet	.70	1.62	82.69	14.99	.47	.1912
			Dry		1.63	83.27	15.10	.47	

An interesting series of tests was made on coal from Shumway, Huerfano County, in the noncoking portion of the field. Four trials were made under different conditions, as shown in the following table, without producing coke:

Coking tests of coal from Shumway.

	Test 209.	Test 210.	Test 211.	Test 214.
Date	1,19,08	1,20,08	1,22,08	1,30,08
Duration ... hours	80	36	43	60
As shipped	Nut.	Nut.	Nut.	Nut.
As used[a]	w., f. c.	w., f. c.	w., [illegible] in.	r., [illegible] in.
Coal charged:				
Wet ... pounds	10,220	7,730	9,520	9,790
Dry ... do	9,569	7,238	8,729	9,198
Coke produced	None.	None.	None.	None.

[a] w., Washed; f. c., finely crushed; r., raw.

Remarks.—Test 209: Charge burned very rapidly, but developed no cracks. At no stage was there any evidence of pasty condition or other signs of coking.

Test 210: Charge burned with small draft and exhibited only few widely separated cracks. Volatile driven off, but resultant product did not stick together.

Test 211: Effort to coke not crushed. Volatile driven off down about 12 inches and under this unburned coal.

Test 214: This test made to ascertain if washing might possibly have destroyed coking qualities. Volatile driven off as in test 211; no evidence of coking.

Chemical analyses of coal from Shumway used in the above tests.

Test No.	Laboratory No.	Condition of coal.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.
209 210	241-D	Wet	6.37	37.11	44.57	11.95	0.89
		Dry		39.63	47.61	12.76	.96
211	242-D	Wet	8.31	37.44	42.04	12.21	.84
		Dry		40.82	45.86	13.32	.92
214	240-D	Wet	6.05	35.45	39.64	18.86	1.04
		Dry		37.73	42.19	20.08	1.11

Tests were also made by mixing coal from Sopris with the coal from Shumway in an attempt to ascertain the possibility of producing coke from noncoking coal by the addition of good coking coal. The results seem to indicate that noncoking coal acts simply as a diluent.

Coking tests of mixed samples of coal from Sopris and Shumway.

	Test 220.	Test 224.
Date	2,9,08	2,14,08
Duration ... hours	25	22
Size:[a]		
As shipped	3-in. nut, r. o. m.	3-in. nut, r. o. m.
As used	w., f. c.	w., f. c.
Coal charged:		
Wet ... pounds	8,250	6,210
Dry ... do	7,814	5,809
Coke produced:		
Wet ... do	5,222	3,365
Dry ... do	5,216	3,318
Weight ... per cent	63.30	54.19
Dry ... do	66.75	57.12
Breeze produced:		
Wet ... pounds	177	513
Dry ... do	177	506
Wet ... per cent	2.14	8.26
Dry ... do	2.27	8.71
Total yield:		
Wet ... do	65.44	62.45
Dry ... do	69.02	65.83

	Test 220.	Test 224.
Physical properties of coke:		
Specific gravity—		
Apparent	1.11	1.00
Real	1.93	1.86
Volume—		
Coke ... per cent	58.00	54.00
Cells ... do	42.00	46.00
Weight ... per cubic foot—		
Wet ... pounds	95.36	90.18
Dry ... do	69.15	61.49
6-foot drop test over 2-inch mesh—		
1 ... per cent	97.50	96.50
2 ... do	93.00	94.00
3 ... do	90.50	88.50
4 ... do	89.00	84.00
5 ... do	90.50	84.50

[a] r. o. m., Run-of-mine; w., washed; f. c., finely crushed.

Remarks.—Test 220: Proportions 1 to 3. Coke light-gray color. Cell structure good. Breakage cross fractured and irregular, but pieces of good size; 6-inch cubes. Mixture of noncoking Shumway coal appears to have opened cells.

Test 224: Proportions 2 to 1. Coke dull-gray color; soft, dense, punky. Cell structure exceeding small, only visible by means of magnifying glass. Breakage very poor and irregular, cohesion slight. Percentage of breeze very large.

That the coal in the southern part of the field will coke and that in the northern part will not is an interesting and economically important fact, but the cause of the difference is not known. The reason why some coals can be made into coke and others can not has long been a mystery. New light has recently been thrown on the subject by David White,[a] who suggests that the coking property of some coals at least is due to the presence of gelatinous algæ in the original ingredient matter of which the beds are composed. The presence of such ingredients, he affirms, would tend to cause relatively high hydrogen and low oxygen, features that have been observed to characterize coking coals. White suggests that the hydrogen-oxygen ratio on a dry-coal basis indicates whether a coal will coke or not, and states that if the ratio (H:O) is 59 per cent or more the coal is "almost certain to possess coking fusibility," the figure being obtained by empirical tests. So far as the Trinidad field is concerned it is a fact that the hydrogen-oxygen ratio of the coking coals is greater than 59 per cent and that of the noncoking coals is less. In such an area as the Trinidad field, however, where there is coking coal at one end of the basin and noncoking coal at the other end, and where there can be no doubt that the coals in the two portions of the field, if not actually the same beds, certainly belong to the same group, it seems more likely—at least in the absence of data to the contrary—that the varied coking quality is due not so much to differences in original ingredient matter as to differences in the metamorphic action to which different parts of the basin have been subjected; but the entire subject is very obscure. It is noteworthy that the analyses show a distinct difference in composition of the coals in the northern and southern areas of this field—a fact which suggests, as already stated, that the coking quality of the coals is connected with the general regional metamorphism that the beds have undergone. The coking coals of the southern part of the field are the more highly altered beds, containing relatively more carbon and hydrogen and less oxygen, the noncoking coals in the north being less metamorphosed.

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[a] White, David, The effect of oxygen in coal: Bull. U. S. Geol. Survey No. 382, 1909, pp. 48-54.

STATISTICS.

AMOUNT OF AVAILABLE COAL.

Because of the varied occurrence of the coal, the uncertain amount which has been made useless by the intrusion of igneous rocks, and the large unexploited central area, it is impossible at present to estimate at all closely the total available quantity. The following figures therefore are only a very rough approximation.

The area included by the outcrop of the lowest coal group between the state boundary on the south and an arbitrary line across the north end of the field is 1,115 square miles. Of this about 80 square miles in the vicinity of the Spanish Peaks may be considered negligible both on account of the great depth[a] of the coal beneath the surface and on account of its destruction, in part of the area, by the intrusion of a great volume of igneous rocks. The area of available coal land, therefore, in the Trinidad field is about 1,035 square miles. To obtain a conservative estimate it can be assumed that the total amount of coal of workable thickness may be represented by a single bed 5 feet thick extending throughout the field. This figure is the average of 106 measurements of coal beds in the lower group. In the estimate the coal in the middle and upper groups is considered as offsetting the destructive effect of igneous rocks. On the basis of one bed of coal 5 feet thick occupying an area of 1,035 square miles, there was originally 5,860,998,000 short tons of coal in the Trinidad field.

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[a] In estimating the extent of this excluded area, a depth of 3,000 feet has been regarded as the maximum limit to which coal can be profitably mined under present conditions in this country.

PRODUCTION AND VALUE.[a]

In 1908 Colorado ranked sixth among the States in the value of its coal production and eighth in the amount of coal produced, the output of the State being 9,634,973 short tons, valued at $13,586,988. These figures, on account of the unfavorable trade conditions due to the business panic, are considerably less than those for 1907, but advance data indicate that the tonnage for 1909 exceeded that of 1907, which was the largest in the history of the State. Of the total amount mined in 1908 the Trinidad coal field produced 5,834,869 short tons, valued at $7,499,159, which is more than 62 per cent of Colorado's total tonnage. The following table shows the production and value of coal mined in the Trinidad field from 1892 to 1908, inclusive:

Production and value of coal in the Trinidad field, Colorado, 1892 to 1908.

Year.	Las Animas County.			Huerfano County.	
	Quantity.	Made into coke.	Total value.	Quantity.	Value.
	Short tons.	*Short tons.*		*Short tons.*	
1908	4,190,801	1,113,450	$4,854,651	1,644,068	$2,644,508
1907	4,885,105	1,547,848	5,658,606	1,797,790	2,799,133
1906	4,768,882	1,666,924	4,856,949	1,803,791	2,502,924
1905	4,297,599	1,844,441	4,257,186	1,426,640	1,958,148
1904	2,808,953	848,182	2,977,215	1,187,905	1,754,904
1903	3,213,743	1,106,798	3,191,565	1,319,666	1,757,722
1902	3,245,271	1,234,470	2,919,146	1,189,313	1,446,866
1901	2,476,138	801,108	2,197,567	918,609	1,063,403
1900	2,123,411	749,222	1,808,996	854,944	912,110
1899	2,125,143	647,610	1,863,876	632,577	727,721
1898	1,211,340	354,292	1,100,022	1,075,881	1,185,244
1897	1,427,526	337,670	1,359,022	367,894	402,773
1896	1,261,555	306,185	1,185,113	353,338	375,228
1895	1,253,149	303,351	1,212,527	386,696	402,965
1894	1,153,863	316,449	1,167,174	408,045	441,130
1893	1,587,338	336,735	1,610,366	521,205	600,651
1892	1,171,069	295,106	1,433,897	541,733	1,083,466
	43,200,886	13,809,841	43,653,878	16,430,095	22,058,896

Prior to 1892 complete data were not kept, but from the figures available, which go back to 1873, it is estimated that the total production of the Trinidad field down to and including 1908 is, in round numbers, 68,800,000 tons.

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[a] Mineral Resources U. S. for 1908, pt. 2, U. S. Geol. Survey, 1909.

OLATED COAL FIELDS IN SANTA FE AND SAN MIGUEL COUNTIES, NEW MEXICO.

By James H. Gardner.

INTRODUCTION.

In the early spring of 1908 the writer examined certain isolated al fields in Sandoval, Santa Fe, and San Miguel counties, N. Mex., connection with the classification of public lands. The fields sited were the Una del Gato, Cerrillos or Madrid, Omara, and cos River. The first three are probably detached portions of a ce continuous field which covered a wide area previous to the uplift the Ortiz and neighboring mountains. A brief report on the Una l Gato field, by M. R. Campbell,[a] was published in 1907. The rrillos or Madrid region has been visited by numerous geologists d well described in a report by D. W. Johnson[b] for the Columbia hool of Mines. The Madrid anthracite has attracted the attention mining men and scientists for many years. It is the result of a cal intrusion of andesite that through heat and pressure has metaorphosed subbituminous coal to high-grade bituminous and anthrate. The reports, above cited, on the Una del Gato and Cerrillos lds are fully descriptive of those fields, and it is scarcely necessary add to them in this brief paper.

OMARA COAL FIELD.

The Omara coal field is a small area of coal-bearing rocks located out 16 miles by wagon road southeast of Madrid and about 12 iles northeast of San Pedro. The larger amount of the output of e field has been used at San Pedro by the Santa Fe Gold and Copper ompany. The area of workable coal so far as determined is confined sec. 32, T. 13 N., R. 9 E., New Mexico principal meridian. Only e mine is in operation—the Block Coal or Omara mine, operated the Lewisohn Coal Company. This mine, which is located in the . ½ SE. ¼ SW. ¼ sec. 32, has been worked intermittently for a number of years. A slope enters in a direction N. 60° E., at a slight dip, on a bed 30 inches thick. This bed has a massive sandstone cover 9 feet thick, above which is a second coal bed 4 feet 6 inches thick, also capped by a massive sandstone. Apparently these sandstones are of fresh-water origin; their direct contact with underlying coal beds suggests either an abrupt change in the physiography of the region at the end of each coal-forming period or a slight unconformity. The two beds are very inconstant in thickness. At one point, 560 feet down an old slope on the upper bed near the present mine, the coal abruptly disappeared against a solid face of sandstone, showing no evidence of a fault. The entry was turned in another direction and the workings were continued. The writer, in company with Norberto S. Torres, superintendent of the mine, entered the old slope and made an examination of this portion of the workings. It was found that the disappearance of the bed was due to the total erosion of the coal previous to the deposition of the overlying sandstone, which is thus brought into juxtaposition with the floor of the coal bed. This is a condition which is likely to be encountered where a massive sandstone rests directly on a coal bed.

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[a] The Una del Gato coal field, Sandoval County, N. Mex.: Bull. U. S. Geol. Survey No. 316, 1907, pp. -430.

[b] Geology of the Cerrillos Hills, New Mexico: Columbia School of Mines Quart., 1907, pp. 303-350.

The following is the section exposed at the Block Coal mine:

Section of coal bed in Block Coal mine.

	Ft.	In.
Covered by débris from Santa Fe formation.		
Sandstone, massive	?	
Coal	4	6
Sandstone, massive	9	
Coal	3	
Shale, hard, dark.		
	16	6

The coal of these beds is black, bright, and hard, being similar in appearance to the bituminous coal of the Madrid district. At a distance of 350 feet N. 60° E. down the main entry a basaltic dike 45 feet thick was encountered. This dike, with a nearly north-south strike, stands above the surface as a prominent wall in the western part of sec. 32. The main entry was driven straight through the dike and the coal bed was found in normal position on the east side. Workings on the upper bed also were begun east of the dike. For a distance of 20 feet on either side of it the coal is harder and more nearly semianthracite, and the coal in immediate contact with the basalt is slightly prismatic in structure, but on the whole the coal has apparently been very slightly altered by this intrusion. It is probable that the general quality of the entire bed as exposed by the underground workings has been improved by thermal conduction from this dike, transmitted either through the coal itself or through the massive sandstone covers of each bed. As the thermal conductivity of dry sandstone is about five times the maximum conductivity of coal,[a] it is highly probable that at points distant from the dike the coal would be appreciably affected by heat conducted through the sandstones lying directly on the coal beds.

The Omara field is apparently confined to a very small area surrounding the mine. A quarter of a mile south and west of the mine a massive sandstone is exposed which occurs about 100 feet below the coals. Below this is a broad level plain of shale of Montana age stretching away to the southwest toward the southern part of the Ortiz Mountains. On the northwest and southeast, at distances of less than a mile each, the coal field is apparently limited by faults but is largely concealed by débris from the Santa Fe formation. The Santa Fe is of Tertiary age and lies unconformably over the older geologic formations. These beds were named by Hayden, who visited the Cerrillos district in 1869.[b] Johnson[c] has shown, by a detailed study of these unconformable beds and of the general physiography of the region, that they are the result of confluent alluvial fans from the surrounding mountains and extend in age from the Loup Fork (Tertiary) to the present time.

The Omara coal field is limited by the large basaltic intrusion of Pelon Mountain, less than a mile to the northeast. It seems highly probable that workable coal will not be found in the district except from the central portion of sec. 32 northward to the north line of sec. 29. As each of the coal beds is capped by a massive sandstone, it is impossible to say from a surface examination what conditions may be met in the underground workings. The coal-bearing formation is probably of the same age as the beds in the Madrid field and corresponds closely, if not exactly, with the Mesaverde formation of the San Juan Basin.

CARBONIFEROUS COAL ON PECOS RIVER.

In April, 1908, the writer inspected areas of reported coal in Tps. 16 and 18 N., R. 12 E. An abandoned drift is located in the E. ½ NE. ¼ SE. ¼ sec. 5, T. 16 N., R. 12 E., in the west cliffs of Pecos River about 5 miles above the town of Pecos. This drift, formerly known as the Gould & Thomas mine, enters in a direction N. 65° W. on a very irregular coal bed, showing an average thickness of 20 inches. About 120 feet from the surface the bed thickens locally to 40 inches, but 225 feet back it shows only 10 inches. It was readily seen that this coal bed occurs in the Carboniferous system, and this observation was later verified by a collection of Pennsylvanian fossil invertebrates from the rocks both above and below the coal bed.

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[a] Everett, J. D., C. G. S. system of units, London, 1891, pp. 125-127.

[b] U. S. Geol. Survey of Colorado and New Mexico, preliminary field report, 1869, pp. 66-68.

[c] Johnson, D. W., op. cit., pp. 328-332.

The following is a generalized section along the river above Pecos:

Generalized section along Pecos River above Pecos, N. Mex.

	Feet
Sandstone, shale, local conglomerate and limestone, the whole variegated, red predominating	?
Limestone with some alternating shale and sandstone	100
Limestone containing *Derbya cymbula*, *Derbya bennetti*, *Productus inflatus* (?), *Productus inflatus?* var., *Spirifer rockymontanus*, *Spirifer cameratus*, and *Composita subtilita*	5
Limestone with some alternating shale and sandstone	1,000
Limestone containing *Derbya bennetti*, *Productus inflatus?* var., *Spirifer rockymontanus*, *Composita subtilita*, and *Cliothyridina orbicularis*	5
Limestones with some alternating shale and sandstone	350
Limestone containing *Derbya bennetti*, *Productus inflatus?* var., *Spirifer rockymontanus*, and *Composita subtilita*	5
Limestone, massive	50
Limestone, shaly, containing *Zaphrentis* sp., *Productus inflatus?*, *Productus inflatus?* var., *Productus* aff. *wallacianus*, *Marginifera* aff. *muricata*, *Marginifera* aff. *splendens*, *Rhynchoporaillinoisensis*, *Spirifer rockymontanus*, *Squamularia perplexa*, *Cliothyridina orbicularis*, *Hustedia mormoni*, and *Phillipsia* sp	1⅔
Sandstone, calcareous	3
Shale	1
Coal	Varying.
Limestone and sandstone	30
Shale containing *Derbya bennetti*, *Productus inflatus?* var., *Spirifer rockymontanus*, and *Composita subtilita*	10
Covered, about	200
Limestone, about	50
Pre-Cambrian complex.	
	1,810⅔

George H. Girty is disposed to think that the fossils indicate rocks rather low in the Pennsylvanian series.

Another prospect drift was visited in the NE. ¼ NE. ¼ sec. 28, T. 18 N., R. 12 E. This is also in the west cliffs of Pecos River. It was opened in 1905 by O. W. Alexander, manager for the Pecos Copper Company, located at Cowles. The coal bed is reported as being too thin and the coal too poor in quality to be of commercial value. The following is the section at the mine:

Section of coal bed in Cowles mine, in sec. 28, T. 18 N., R. 12 E.

	Ft.	in.
Limestone.		
Sandstone, massive	7	
Shale	1	
Coal		7-15
Shale		6
Shale, sandy.		
Covered.		

A sample of the coal was sent to the Survey laboratory at Pittsburg, Pa., where the following analyses were made under the direction of F. M. Stanton:

Analysis of coal from Cowles mine.

[Laboratory No. 6862. Air-drying loss, 0.90 per cent.]

	As received.	Air dried.	Dry coal.	Pure coal.
Moisture	1.72	0.83	....	....
Volatile matter	22.27	22.47	22.66	30.23
Fixed carbon	51.39	51.86	52.29	69.77
Ash	24.62	24.84	25.05	....
Sulphur	2.75	2.78	2.80	3.74

It will be seen from the above analysis that the coal is very high in ash. Owing to its low grade as a fuel and the very meager quantity available, it is of little commercial importance at the present time.

The coal beds of the Pecos River region are extremely interesting geologically. The limestone, sandstone, and shale with which these beds are associated are the lowest and oldest of the stratigraphic section in this region. They rest directly on the pre-Cambrian complex that is exposed farther west in the Santa Fe Mountains. As they are positively correlated with the Pennsylvanian of the East, it is interesting to note that even though they are in large part marine, still the presence of coal beds in them indicates that conditions prevailed here for a time such as characterize the series in the eastern part of the United States.

THE CARTHAGE COAL FIELD, NEW MEXICO.

By JAMES H. GARDNER.

INTRODUCTION.

The following brief report contains the results of an examination of the Carthage coal field, New Mexico, in February, 1908, relative to the classification of public lands in that area. The Carthage field is located 12 miles southeast of San Antonio, Socorro County, in T. 5 S., R. 2 E. One of the first coal mines in New Mexico was opened in this field in 1861 by government troops encamped on the Rio Grande; the same mine is in operation to-day and is known as the Government mine.

As this field is located some distance from the main line of travel along the valley of the Rio Grande, the problem of transportation has given considerable trouble and the facilities for placing the coal on the market have varied greatly from time to time. In 1881 the Santa Fe Railway Company built a branch line to the field, but this line was operated only until 1894, when it was abandoned on account of a seemingly well-authenticated report that the coal beds were about exhausted. This report, however, seems to have been without foundation, for later and more careful examinations of the region revealed the presence of workable coal in considerable quantity and mining was resumed; but the operators were badly handicapped by having to haul their coal in wagons 12 miles to San Antonio in order to send it to market. The mines were operated on this basis until August, 1906, when the New Mexico Midland Railroad was built along the same right of way as the old branch of the Santa Fe. This new line, operated by the Carthage Fuel Company, delivers to the Santa Fe Railway, which offers an all-rail route for the coal from Carthage to El Paso and other places in the South and Southwest. There are now four active mines in the field—the Government, Bernal, and Hilton mines of the Carthage Fuel Company and the Emerson mine of Emerson & Allaire. The operators of the Emerson mine still haul their coal in wagons to the railroad at San Antonio.

GENERAL GEOLOGY.

STRATIGRAPHY.

The coal-bearing rocks of the Carthage field (see Pl. XXI) as revealed by the drill contain the Carthage coal bed, with an average thickness of 5 feet, besides several small beds from 1 inch to 8 inches thick. All the mines of the field are on the Carthage bed, opened originally at the Government mine. The geologic age of these coal beds has been a disputed question. The writer collected fossil invertebrates both above and below the Carthage bed which were examined by T. W. Stanton. The fossils found below the coal bed consist of species characteristic of the Benton fauna and agree with collections previously obtained in the neighborhood of Carthage by Willis T. Lee and others. The fossils obtained 35 feet above the coal are brackish-water forms, consisting mostly of types which range from a horizon near the base of the Colorado up to the Laramie. Doctor Stanton states, however, that he believes the coal to be older than the Laramie and probably to lie within the limits of the Montana. This suggestion agrees with the conclusions resulting from the writer's studies of the stratigraphy and correlations based entirely on lithologic evidence. The character of the coal-bearing formation and its conformable relations to the underlying shale, which contains a Benton fauna, strongly suggest that it is either upper Colorado or lower Montana. The similarity of the coal-bearing formation to that of other fields of New Mexico, the geologic age of which is known, leads the writer to believe that it is Montana and in age corresponds closely if not exactly with the Mesaverde formation of the San Juan Basin.

The Carthage field is the southernmost of the productive coal fields in this portion of the Southwest. The so-called Engle coal field[a] lies 70 miles farther south, but as yet no coal bed of workable thickness has been reported from that district. The relation of the coal-bearing formation of the Carthage field to that of the Engle field is not known, but it is probable that they are of approximately the same age.

In the vicinity of Carthage a series of red and variegated shales, sandstones, and coarse conglomerates rests unconformably upon the coal-bearing formation, which consists of tan-colored sandstone and drab shale. These variegated beds dip to the south and east beneath late Pleistocene clay, sand, gravel, and sedimentary débris that cover the whole interior of the great desert synclinorium known as the Jornada del Muerto and form prominent terraces in the valley of the Rio Grande. In this part of the Jornada del Muerto the Pleistocene beds contain notable amounts of gypsum that may have been eroded from immense deposits some 20 miles northeast of Carthage, occurring probably in the Carboniferous system.

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[a] Lee, W. T., The Engle coal field, New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, p. 240.

This recent unconsolidated material obscures the underlying variegated beds and coal-bearing formation throughout the region bordering the Carthage field. At Carthage the underlying rocks are brought to the surface by a comparatively recent disturbance which produced an extremely complex and irregular system of faults. The writer was fortunate in finding fragments of bone and one tooth of a mammal in the variegated beds overlying the coal-bearing formation. The tooth was reported as possibly *Palæosyops* by J. W. Gidley, who regards it as certainly of later age than the Wasatch epoch and probably about the same as the Bridger. Because the variegated beds (Tertiary) have been confused with the much older red beds of the upper Carboniferous and Triassic (?) systems the area of the coal-bearing formation has been considered by many to be of very small extent. The variegated shale and sandstone under which the coal-bearing rocks dip on the south and east sides of the field have been erroneously considered as belonging normally below the coal-bearing formation and as having been faulted up to the present surface. A careful examination, however, revealed the facts that they contain fossils characteristic of the Bridger formation and that the coarse conglomerate composed of a varied mixture of water-worn sedimentary fragments contrasts very distinctly with the much older Triassic (?) (Jurassic) or Carboniferous [a] beds below.

The following section presents the stratigraphic succession in the Carthage region:

General section of rocks in the Carthage region.

	Feet.
Pleistocene:	
Caliche, white, fine, siliceous	5
Clay and sand, unconsolidated material of Rio Grande valley and Jornada del Muerto	1,000
	1,005
Unconformity.	
Eocene:	
Shale and sandstone, variegated	700
Conglomerate, very coarse bowlders, granite, and sedimentary débris, Carboniferous limestone fragments, etc	200
Shale, red, some sandstone	70
Sandstone, red, very coarse grained, bone fragments and tooth at top	30
Conglomerate, quartz, sandstone, granite, chert, in coarse matrix of granite débris	3
Sandstone, red, some shale	10
Conglomerate, small quartz pebbles	5
Shales, red and drab	5
	1,023
Unconformity.	

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[a] For a description of the lower red beds see Lee, W. T., Note on the red beds of the Rio Grande region in central New Mexico: Jour. Geology vol. 15, No. 1, 1907.

	Feet.
Montana:	
Sandstone, tan-colored and drab shale with traces of coal	600
Shale and thin beds of sandstone. Top contains *Ostrea* sp., *Anomia micronema* Meek?, *Modiola* related to *M. regularis* (White), *Corbicula?* sp., *Corbula* sp., *Melania* sp., and *Admetopsis?* sp	40
Coal, Carthage	5
Shale, drab	20
Sandstone, massive, brown	20
	685
Colorado:	
Shale, drab, with yellowish lime concretions	120
Shale, yellowish, with brown sandstone	45
Sandstone, massive, soft, brown, fossiliferous, containing *Ostrea* sp., *Ostrea lugubris* var. *belliplicata* Shumard, *Pinna* sp., *Pholadomya* sp., *Fasciolaria?* sp., *Prionotropis woolgari* (Mantell)? and *Coilopoceros colleti* Hyatt	15
Shale, drab	40
Shale, drab, with thin brown sandstone	135
Sandstone, massive, gray	10
Sandstone and shale; in center fossiliferous sandstone containing *Inoceramus labiatus*, *Cardium* sp., *Cyprimeria* sp., *Psilomya* sp., *Gyrodes* sp., *Fasciolaria?* sp., and *Volutoderma?* sp	30
Shale, drab	500
	895
Dakota (?):	
Sandstone, hard, gray, in bold hogback, some thin shale	200
Triassic (?):	
Sandstone, dark red, with red and drab shales	1,300
Shale, gray, with pinkish chert inclusions, minute bone fragments	20
Shale, red, and some sandstone	260
Sandstone, red, and red shale	100
Conglomerate with coarse quartz pebbles, dark, white, and yellow	15
Shale, variegated, and red sandstone	300
	1,995
Carboniferous:	
Limestone, bluish-gray, weathers yellowish. Could possibly be used with higher shale for manufacture of Portland cement	200
Grand total	6,003

TOPOGRAPHY AND STRUCTURE.

The Carthage coal field is situated in the highlands dividing the present Rio Grande valley from the desert plains of the Jornada del Muerto. The average altitude of the coal fields is about 5,000 feet, that of the mouth of the slope at the Government mine being 5,032 feet. The topography is that of a plains region, slightly elevated, faulted, and subsequently eroded. Cuestas, or sharp ridges, with the abrupt face along the fault plane and the other face sloping more gently with the dip of the strata, are the prevailing topographic and structural features. These cuestas lie with their longer axes in every conceivable direction and cut across one another without definite system.

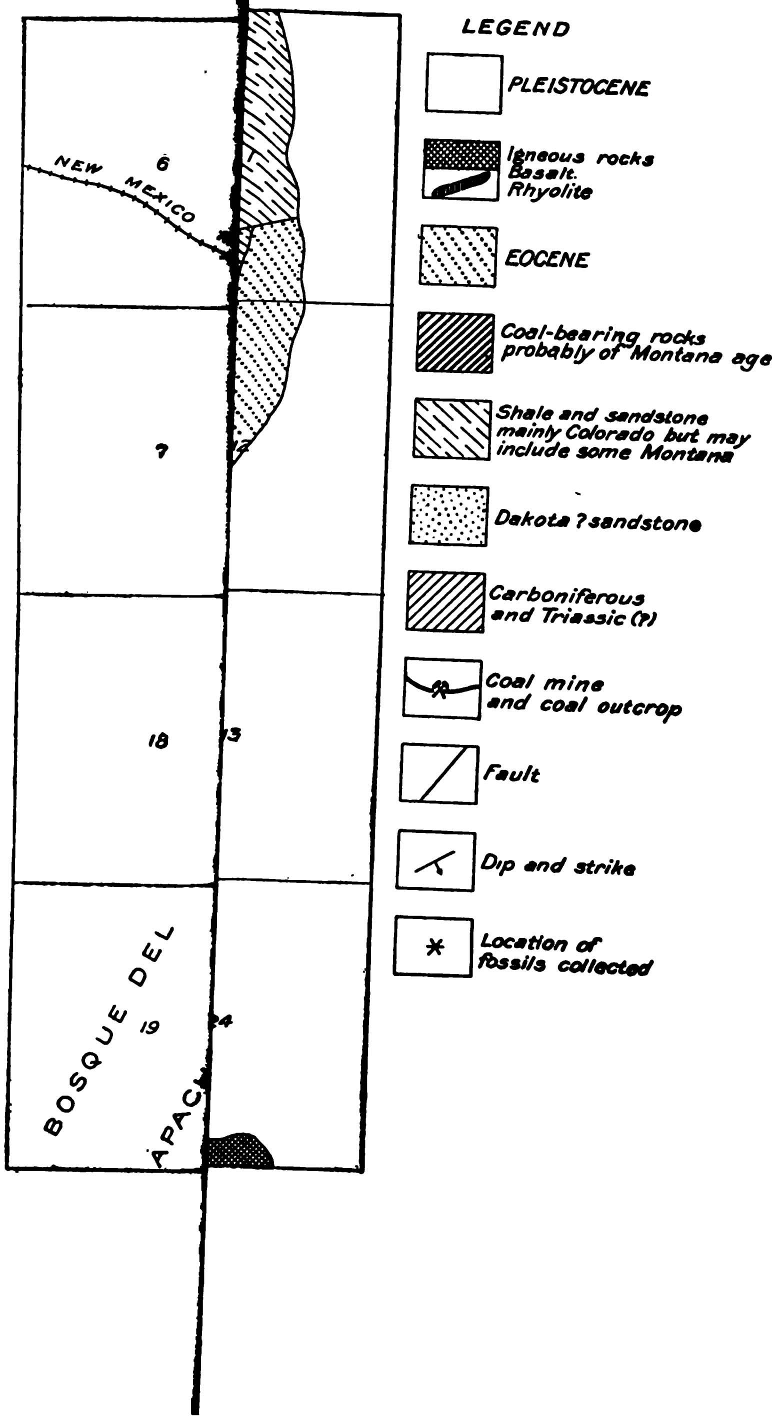
In working the coal mines almost innumerable faults have been encountered. It is often with extreme difficulty that the coal bed, lost at some prominent fault, is discovered in the block beyond. In places entries have been driven ahead in solid sandstone in order to keep the haulage gradient. On account of the numerous faults and changes in dip there is no definite method in extending the underground workings. Even though the mines are in an arid region, considerable expense is entailed on the operators at depths below 200 feet on account of water rushing in along the fault planes and gathering in the lower workings.

It is the writer's opinion that the Carthage field is an exposed continuation of a larger area of coal-bearing rocks lying to the east beneath the Jornada del Muerto.

IGNEOUS ROCKS.

In the southeast quarter of T. 5 S., R. 2 E., there are several prominent volcanic necks consisting of dark basalt, which are known as Cerro Colorado, from local exposures of variegated or reddish rocks reported as occurring around their southern boundary, and also as Spanish Peaks, from their resemblance in form to the peaks of that name in southern Colorado. These peaks are of very recent date and no doubt belong to the same epoch of eruption as the volcanic necks in the vicinity of Engle and the basaltic flows near Albuquerque, San Marcial, and La Mesa, west of Mesilla Valley.

In the NW. $\frac{1}{4}$ sec. 14, just east of the Hilton coal mine, there is a mass of grayish and pink acidic igneous rock which appears to be conformable with the inclosing variegated beds, dipping 15° south of east. The gray rock is a finely porphyritic, holocrystalline variety of hornblende andesite with augite and biotite in less proportions. It contains accessories of magnetite and apatite and considerable secondary calcite and chlorite. The pink rock is similar to the gray variety, but is in the form of a tuff deposited with the variegated beds.


LEGEND
PLEISTOCENE
Igneous rocks
Basalt.
Rhyolite
EOCENE
Coal-bearing rocks probably of Montana age
Shale and sandstone mainly Colorado but may include some Montana
Dakota ? sandstone
Carboniferous and Triassic (?)
Coal mine and coal outcrop
Fault
Dip and strike
Location of fossils collected
NEW MEXICO
6
7
18
13
19
24
BOSQUE DEL
APAC

This rock is probably of the same age and character as the older effusive masses of the Jemes Mountains, the Socorro Mountains, Cerro Magdalen, and the Dona Ana Hills.[a] The fact that a portion of the rock occurs in the form of a tuff bedded with the variegated clay and conglomerate in which a tooth probably of *Palæosyops* was found leads the writer to conclude that this eruption took place during late Eocene time and that probably some of the larger mountain ranges above mentioned were formed at approximately the same time.

The occurrence of this acidic eruptive rock in the elevated and disturbed region about Carthage indicates that it is probably connected beneath the surface with a much larger laccolithic mass; the intrusion of this mass brought up the older sedimentary deposits, including the coal-bearing rocks, into a faulted dome that has subsequently been truncated down to its present level. It is also probable that the metamorphism resulting from this disturbance improved the quality of the Carthage coal by changing it from a subbituminous to a good grade bituminous coal.

THE COAL.

GENERAL CHARACTER.

The coal from the one workable bed of the field ranks in quality with the best coal of the Southwest. It has a black, shiny luster and contains very little physical impurity. It has well-developed vertical joints, which in certain places seem to bear a definite relation to the faults. One system is parallel to a near-by fault; another plane cuts this at right angles, and yet another at about 60°. This arrangement causes the coal to break down in rough prisms, with faces intersecting at angles of 30°, 60°, and 90°.

The coal is said to produce an excellent coke. During the first period of mining in the Carthage field coke ovens were erected at San Antonio and considerable coke was produced, but when the operations of the mines ceased the ovens were torn away and they have not been rebuilt since mining has been resumed, the operators feeling some doubt as to the quantity of workable coal in the district.

A sample of the Carthage coal was collected in the usual manner by cutting a perpendicular channel across the bed from roof to floor, pulverizing the coal to pass a sieve of ½-inch mesh, thoroughly mixing and quartering it, and rejecting opposite quarters until a quart sample remained. This was sealed air-tight in a galvanized can and sent to the laboratory for analysis.

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[a] See Lee, W. T., Water resources of the Rio Grande valley in New Mexico, and their development: Water-Supply Paper U. S. Geol. Survey No. 188, 1907, p. 17.

Analysis of coal from the Hilton mine, Carthage, N. Mex.

[Laboratory No., 6004. Air-drying loss, 1.40 per cent.]

	As received.	Air dried.	Dry coal.	Pure coal.
Proximate:				
Moisture	3.03	1.64	....	....
Volatile matter	38.03	38.57	39.22	42.45
Fixed carbon	51.56	52.29	53.17	57.55
Ash	7.38	7.50	7.61	....
Ultimate:				
Ash	7.38	7.50	7.61	....
Sulphur	.92	.93	.95	1.04
Hydrogen	5.44	4.27	5.26	5.70
Carbon	73.27	74.30	75.56	81.77
Nitrogen	1.13	1.15	1.17	1.26
Oxygen	11.86	11.85	9.45	10.23
Calorific value:				
Calories	7,369	7,474	7,599	8,224
British thermal units	13,264	13,448	13,678	14,803

The above analysis compares favorably with those of choice coals of southwestern Colorado and northwestern New Mexico.

MINE DESCRIPTIONS.

Government mine.—The Government mine is located in the SW. ¼ NW. ¼ sec. 15, T. 5 S., R. 2 E., New Mexico principal meridian. The main entry takes the full dip of 15° S. 32° E. The coal is 5 feet 6 inches to 6 feet thick and has a massive sandstone roof at places, with a few feet of shale intervening. There has been an attempt to work the mine on the single-entry, room-and-pillar plan, but owing to the faulted condition of the coal bed there is no definite method of underground workings. At one point in the mine a gasoline engine draws coal up the dip from four directions.

Bernal mine.—The Bernal mine has two entries to underground workings, an original slope located in the SW. ¼ NW. ¼ SE. ¼ sec. 15; the other, more recently opened, in the NE. ¼ SE. ¼ SW. ¼ sec. 15. The coal bed is 6 feet thick and has a shale roof. A steam hoist transports the coal from the mine up a slope of 12° to 15° to a tipple. Numerous faults having various degrees of throw and direction of strike are encountered in the workings. The new slope of the Bernal mine was opened under the direction of W. L. Weber in 1904.

Hilton mine.—The Hilton mine is located in the NE. ¼ NE. ¼ sec. 15; the bed is 5 feet thick and has either a sandstone or a shale roof, usually the latter; it has an average dip of about 15° SE. In the underground workings numerous faults have been encountered which strike as a rule in a northeast-southwest direction, with downthrow to the southeast. Just beyond the workings on the southeast there are surface exposures of red beds which have been considered Jurassic and Triassic, forming the upthrown side of an immense fault. They are the variegated beds, however, younger than the coal, and the coal undoubtedly continues beneath them.

Allaire (Emerson) mine.—The Allaire mine, also known as the Emerson mine, is located in the SE. ¼ SW. ¼ sec. 9. The coal bed is about 6 feet thick and has shale roof and floor. The main slope takes the full dip of 10° S. to the point where faults change the degree and direction of dip. A new slope has recently been completed and the pillars have been drawn from the old workings. All available coal is said to have been taken out of the old mine, which was bounded by faults too large to warrant the expense of continuing the workings. The coal is brought to the surface by a steam hoist and hauled by wagons to San Antonio.

Abandoned mines.—There have been numerous prospects, drill holes, and old workings in different portions of the field. Unfortunately the maps of former and abandoned workings have been lost to the present operators. The same is true of numerous drill records, etc., which were considered of no value when mining in the field was discontinued.

In the SW. ¼ SW. ¼ sec. 10 is located the Manilla or McIntyre mine, which was closed in 1905. The workings were on the Carthage bed. In the NW. ¼ sec. 16 there are remains of old abandoned slopes, evidently on the Carthage bed. At other points are signs of prospects in connection with the original period of operations.

COAL EXPOSURES 15 MILES NORTH OF THE FIELD.

In connection with the writer's work in the Carthage field he examined an area of reported coal about 3 miles northwest of J. E. Wayne's ranch, about 15 miles north of Carthage, in T. 3 S., R. 3 E., New Mexico principal meridian. In the NE. ¼ SW. ¼ sec. 8 there is a small prospect on a coal bed showing the following section:

Section of coal bed in SW. ¼ sec. 8, T. 3 S., R. 3 E.

	Ft.	in.
Sandstone.		
Shale, yellowish	10	
Shale, brown	2	
Coal		11
Shale	1	
Coal		8
Shale		11
Coal	1	1
Total coal	2	8

The coal dips 26° W. and is associated with sandstone and shale, which form a hogback traceable northward for about 2 miles to the township line. The coal is apparently of very good quality, but is badly separated by shale partings. It is the writer's opinion that this coal belongs to an isolated, faulted area, detached from a larger field to the south that is covered completely by recent unconformable beds. However, it is possible that there was a period of erosion prior to the deposition of the unconformable beds of sufficient duration to have removed all the coals from the greater part of the Jornada del Muerto.

CONCLUSION.

The Carthage field is an extremely faulted region situated along the northwest boundary of the synclinal basin known as the Jornada del Muerto. Only one workable bed is present. This is of excellent quality and is associated with sandstone and shale which are probably of Montana age. The rocks in general dip to the southeast and east beneath younger beds.

The variegated clay, sandstone, and conglomerate which bound the Carthage field on the south and east have been thought by coal operators to be the Triassic (?) or beds below the coal, which have been brought to the surface by faulting, thus limiting the field on this side. These beds, however, contain a late Tertiary fauna and are known to cover the coal rocks unconformably. These later Tertiary beds and Pleistocene deposits cover a region of great extent eastward over the Jornada del Muerto, and it is quite possible that the coal-bearing rocks continue beneath them at a depth of about 3,000 feet.

It has been thought that the Carthage field is a small area preserved by faults. The writer is of the opinion that it is connected with a much larger area to the east and has been exposed by doming, faulting, and erosion. On account of the presence of the variegated beds overlying and obscuring the lower rocks drilling will be necessary to determine the real extent of the field.

THE COAL FIELD BETWEEN SAN MATEO AND CUBA, NEW MEXICO.

By James H. Gardner.

INTRODUCTION.

The brief report presented here is based largely on the results of a few weeks' field work in the spring of 1908. The accompanying map (Pl. XXII) has been constructed in part from reconnaissance maps of the region made by Schrader in 1905 [a] and by the writer in 1907.[b] Acknowledgments are due to Albert L. Beekly for valuable assistance in the field and in the preparation of the map.

The work of the past season was confined to the area south of latitude 35° 45′, and the value of the present report lies chiefly in the stratigraphic correlations as shown on the map. In 1905 Schrader traced the geologic formation across the region necessarily in a very hurried way. At that time the relation of the coal-bearing formation in the southern part of the district was unknown and the formation was called "upper Montana;" but in the season of 1907 it became evident to the writer that the "upper Montana" of Schrader as mapped in the region of San Mateo was equivalent to the Mesaverde as traced eastward from Gallup. In 1906 Schrader traced the Mesaverde around the east side of the San Juan Basin, or Durango-Gallup coal field, into the district here considered, which forms the southeast corner of that immense region. The Mesaverde was traced along the west foot of the Sierra Nacimiento, entering this field just east of Cuba; thence it was followed southward to a point about 10 miles south of Cuba, where its identity was lost, owing to the complicated structure in the vicinity of San Miguel. Schrader suspected that the Mesaverde followed southward from this point along the Sierra Nacimiento and mapped a bold escarpment leading southwestward to San Mateo as "upper Montana." In 1907 the writer traced the lower part of the Mesaverde eastward from Gallup to San

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[a] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, p. 243.

[b] Gardner, J. H., The coal field between Gallina and Raton Spring, New Mexico: Bull. U. S. Geol. Survey No. 341, 1909, pp. 335-351.

Mateo and correlated it with the "upper Montana" at this point. During the past season this formation was mapped eastward from San Mateo to Rio Puerco. In the vicinity of San Miguel the lower member crosses the Puerco, makes a swing to the south around a prominent mesa on the east side of the river, thence continues northward, coinciding with the Mesaverde as traced into the region from the north. The accompanying map shows the closing link in the correlation of the Mesaverde, or lowest important coal-bearing formation, as traced eastward from its type locality in Colorado, southward to Cuba, and westward to San Mateo.

The Mesaverde was mapped from Mesa Verde, Colorado, the type locality, to Gallup, New Mexico, in 1906 by M. K. Shaler.[a] The outcrop of this formation is now known to encircle the San Juan Basin. The same is true of the overlying conformable Lewis shale and "Laramie" formation. The conformable beds below the Mesaverde connect on the south and west with formations in adjacent structural basins of the great plateau province.

GEOLOGY.

STRATIGRAPHY AND STRUCTURE.

On Plate XXII are represented in ascending order six formations—Mesaverde, Lewis, "Laramie," Puerco, Torrejon, and Wasatch. The Mesaverde formation and Lewis shale, as well as the Puerco and Torrejon formations, are grouped together in the legend, for the boundaries of the Lewis and the Torrejon have not been mapped. The Mancos shale in this region includes a transition series of sandstones and sandy shales containing local traces of coal; but as no workable Mancos coal beds are known in the field, there has been no attempt to trace this formation in whole or in part.

The Mesaverde formation is coal bearing throughout the district. The formation here is of about the same character as at other localities in the San Juan region, massive brown and tan-colored sandstones alternating with drab shale and coal beds forming its typical elements. Its thickness is about 1,200 feet. The formation, dipping in a general way northward and westward, lies south of the "Laramie" and covers an area which varies in width from 10 miles on the east to about 40 miles on the west side of the district. This area is not a dip slope, as is the region farther west. Arroyo Chico and Arroyo Torreones have removed a great amount of the Mesaverde strata from the south half of the region and have cut away the dip slope which at one time extended northward from Sierra Chivato to Chacra Mesa. Dutton was impressed by the vast amount of erosion which this region had undergone in recent geologic time. In his report on Mount Taylor and the Zuñi Plateau [a] he considers the chief erosion to have occurred in connection with elevated land and moist climate in the Miocene. Streams then cut nearly to base-level and a later uplift, in Pliocene time, has never been followed by a great amount of erosion, owing to the aridity of climate which has existed until the present day. This idea seems plausible. There has undoubtedly been a period of powerful erosion at some time previous to the Pleistocene and subsequent to the Wasatch (Eocene). As the Miocene seems generally to have been characterized by terrestrial degradation, it is probable that the greater amount of erosion and canyon cutting occurred at that time. The altitude of the Mesaverde area increases toward the north, from 6,200 feet along Arroyo Chico to 7,000 feet on Chacra Mesa. This increase in altitude is gradual and in the same direction as the general dip (3°) of the strata. In passing northward from Arroyo Chico one encounters numerous extremely irregular low escarpments that form a series of steps stratigraphically as well as topographically higher, until he reaches the topmost strata of the Mesaverde at the summit of Chacra Mesa.

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[a] A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. U. S. Geol. Survey No. 316, 1906, pp. 376–426.

The Lewis shale in this region is very irregular in composition and contains a notable amount of thin shaly sandstone and sandy shale. Its thickness varies, but in few places exceeds 200 feet. The Lewis shale occurs along dip slopes of the highest sandstone of the Mesaverde usually covered by a dense growth of chico and sagebrush. The shale can not be closely mapped except by extremely detailed work involving a great amount of time. It seems sufficient to say that the Lewis shale forms a comparatively narrow irregular belt south of the "Laramie" boundary.

The "Laramie" formation contains important coal beds in the vicinity of Raton Spring and farther west, but does not include any large coal beds where it disappears beneath the Puerco formation, 10 miles southwest of Cuba. The Puerco lies unconformably on the "Laramie" and covers all but a few hundred feet of the lower part of the formation, which is elsewhere the coal-bearing portion. The "Laramie" formation is made up of a massive sandstone at the base, with overlying tan-colored and gray sandstones alternating with drab and brownish shales and thin beds of subbituminous coal.

The Puerco formation consists chiefly of variegated shale and soft sandstones. At its base, however, is a massive sandstone member which can be traced with definiteness across the area. The formation varies in thickness from 800 to 900 feet. It completely covers the "Laramie" in the vicinity of Cuba, where it is typically exposed along Puerco River.

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[a] Sixth Ann. Rept. U. S. Geol. Survey, 1885, p. 190.

Unconformably above the Puerco lies the Torrejon formation, in exposures of varying thickness, because of a prominent unconformity at the top as well as at the bottom. In general appearance the Torrejon is similar to the Puerco and was included in the original Puerco of Cope.[a] At the point where Torrejon fossils were collected by the writer the formation can not be over 300 feet thick.

The Wasatch formation consists of variegated shale, conglomerate, and soft sandstone similar in appearance to the Puerco and Torrejon, but containing a smaller percentage of sand. It rests unconformably on lower rocks. North of Cuba the Wasatch rests horizontally against the Sierra Nacimiento, covering the Puerco, which is tilted to perpendicularity. In thickness the Wasatch formation ranges from 1,000 to 1,500 feet. It contains an abundant vertebrate fauna.

VOLCANIC ROCKS.

Seven miles southeast of San Mateo is Mount Taylor, which has been well described by Dutton.[b] This is a volcanic cone that rises to an altitude of 11,390 feet and is surrounded by a lava plateau having a length of 47 miles in a northeast-southwest direction and an extreme width of 23 miles. This plateau is known as the Mount Taylor Mesa. Its northeastern portion is shown on the accompanying map (Pl. XXII). This mesa was formed by a series of lava flows from Mount Taylor and numerous surrounding vents. Within the mesa itself are many volcanic cones; a cluster of these in the central portion forms the group known as Sierra Chivato. In the walls of the mesa are a number of peaks that disclose volcanic necks as well as the lava which flowed from them. Farther out and isolated from the mesa are numerous volcanic plugs, typified by Alesna and Cabezon peaks. These prominent peaks testify to the original extent of the lava plateau and the great amount of erosion subsequent to the eruptions. Across the valley of Puerco River is Prieta Mesa, which was originally connected with Mount Taylor Mesa by lava flows from vents now marked by plugs left standing in the valley between them. Some of these plugs have been eroded below the level of the lava mesas on either side of the valley. These volcanoes and lava flows are not so recent as the lava in the valley of the San Jose west of Mount Taylor. Dutton considered the initial outbreaks to have occurred in the early Miocene epoch. Small dikes are not uncommon, but they do not form prominent features in the topography.

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[a] Cope, E. D., Rept. Chief of Engineers, 1875, appendix LL, p. 1012.

[b] Dutton, C. E., Mount Taylor and the Zuñi Plateau: Sixth Ann. Rept. U. S. Geol. Survey, 1885, pp. 164-182.

THE COAL.

COAL-BEARING FORMATIONS.

The coal beds of the region between Cuba and San Mateo are confined to two geologic formations, the Mesaverde and "Laramie."

The Mesaverde constitutes the surface formation over the greater portion of the area and contains the best coal beds. The extreme upper and lower members of the formation bear coal beds of considerable thickness; the beds in the central portion of the formation are thin. The lowest coal beds are concealed beneath the lava flow of Mount Taylor Mesa for a distance of 28 miles northeast from San Mateo toward Cabezon. Coal beds higher in the Mesaverde, but near the base of the formation, outcrop around the north side of the mesa. The coal-bearing rocks near the top of the formation are confined to Chacra Mesa and its continuation northwestward to Pueblo Alto. This mesa passes beyond the limits of the district mapped and is continuous with the upper escarpment of the Mesaverde along the south side of Chaco Canyon to Sulphur Spring. At the latter point the escarpment comes into close proximity with the one formed by lower Mesaverde beds that outcrop along the west side of the basin; the two series of beds continue northward in the Grand Hogback of San Juan River, then swing to a horizontal position and form Mesa Verde itself.

The "Laramie" formation contains coal beds of poor quality in the vicinity of Raton Spring and farther west. The important coal beds disappear 10 miles east of Raton Spring, and the formation conains very thin beds from that point northward to the Colorado state line.

MESAVERDE COAL BEDS.

Locality 1:[a] In sec. 9 of San Mateo Township (T. 13 N., R. 8 W.) the Mesaverde swings around a small mesa. In the west face of this mesa, 100 feet from the top, there is a coal bed 3 feet thick, with carbonaceous shale immediately above and below. The coal bed dips 5° E. It is apparently of fair quality and probably identical with the bed exposed in the next township north.

Locality 2: From the east side of sec. 34, T. 14 N., R. 8 W., the boundary of the Mesaverde encircles the San Mateo anticline and returns to the west side of sec. 35. From this point the boundary passes westward around the mesa in sec. 9 and thence southward to the point of disappearance beneath the lava surrounding Mount Taylor.

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[a] Numbers correspond with those used on Plate XXII.

In the central portion of sec. 27 is a coal bed about 20 feet below a massive sandstone 60 to 100 feet thick, which caps the escarpment at that point. This bed shows the following section:

Section of coal bed at locality 2, T. 14 N., R. 8 W.

	Feet.
Sandstone, massive	60–100
Shale	20
Coal	4⅙
Shale, sandstone, and thin coal beds	210
Covered.	
	294–334⅙

Locality 3: A coal bed was observed in the northwestern portion of sec. 2, T. 14 N., R. 8 W. The section is as follows:

Section of coal bed at locality 3, T. 14 N., R. 8 W.

	Ft.	in.
Shale, sandy	10	
Coal	2	6
Shale		6
Coal	1	8
Shale	4	
Covered.		
	18	8

Locality 4: At locality 4, in T. 15 N., R. 7 W., the following section was obtained in rocks practically horizontal. The coal contains a large amount of resin.

Section of coal bed at locality 4, T. 15 N., R. 7 W.

	Ft.	in.
Sandstone	1	
Shale	2	
Coal	1	3
Shale		1
Coal	2	8
Shale, carbonaceous	12	
	19	

Locality 5: In the southern part of the same township the following section was made:

Section of strata at locality 5, T. 15 N., R. 7 W.

	Ft.	in.
Sandstone, massive	10	
Shale, drab	1	
Shale, carbonaceous; contains fossil leaves		6
Coal	1	
Shale, carbonaceous		6
Shale; contains poor leaves	1	
Shales, covered.		
	14	

Locality 6: A coal bed of fair quality is exposed in the western portion of T. 15 N., R. 6 W., on the Felipe Tafoya grant. The following is the section of the bed, which dips slightly south at this point:

Section of coal bed at locality 6, T. 15 N., R. 6 W.

	Ft.	In.
Shale	3	
Coal, bony		8
Coal	1	10
Shale, covered.		
	5	6

Locality 7: A coal bed, apparently of good quality, as shown by weathered outcrops, is exposed in the eastern part of T. 16 N., R. 6 W., with the following section:

Section of coal bed at locality 7, T. 16 N., R. 6 W.

	Ft.	In.
Shale	10	
Coal	2	6
Shale	4	
Covered.		
	16	6

Locality 8: In the northwest corner of T. 16 N., R. 5 W., a coal bed of medium quality was observed. This bed is in all probability at the same horizon as the section at locality 7 and has the following section:

Section of coal bed at locality 8, T. 16 N., R. 5 W.

	Ft.	In.
Sandstone.		
Shale	10	
Coal	2	6
Shale, covered.		
	12	6

Locality 9: In the southern half of T. 16 N., R. 5 W., a coal bed is exposed at numerous places. At locality 9 the bed attains a thickness of 3 feet 6 inches, with shale above and below. This coal is of fair quality, to judge from its general appearance on weathered exposure. The bed is exposed in numerous small mesas or outliers and probably corresponds with the coal bed of localities 7 and 8, given above.

Locality 10: In the central part of T. 16 N., R. 4 W., a coal bed showing a surface thickness of 4 feet 6 inches is exposed. The coal is apparently of fair quality and free from partings, as shown by the following section:

Section of coal bed at locality 10, T. 16 N., R. 4 W.

	Ft.	In.
Sandstone.		
Shale, sandy	15	
Shale, brown, plastic		6
Coal	4	6
Shale, brown	5	
Shale, sandy	15	
Covered.		
	40	

Locality 11: In the southeast corner of T. 17 N., R. 5 W., the following bed was observed at locality 11:

Section of coal bed at locality 11, T. 17 N., R. 5 W.

	Ft.	In.
Shale.		
Coal	3	2
Shale	8	
Coal		4
Shale.		
	11	6

Locality 12: In the southeastern part of T. 17 N., R. 4 W., the following section was made in rocks dipping 2° N.:

Section of strata at locality 12, T. 17 N., R. 4 W.

	Ft.	In.
Sandstone, massive, brown	3	
Shale, drab	33	
Shale, carbonaceous	10	
Coal	2	3
Shale, drab	2	
Coal	2	3
Shale, drab	5	
Covered.		
	57	6

Locality 13: In the central part of T. 17 N., R. 3 W., the following section was measured:

Section of strata at locality 13, T. 17 N., R. 3 W.

	Ft.	In.
Sandstone	15	
Shale	10	
Coal	3	
Shale, carbonaceous	18	
Coal	1	10
Shale	1	
Sandstone, coarse, gray	10	
	58	10

Locality 14: At locality 14, 8 miles down Rio Puerco from San Miguel, in unsurveyed territory, the following section is exposed:

Section of strata at locality 14, 8 miles below San Miguel.

	Ft.	In
Shale, drab	12	
Sandstone		8
Coal, poor quality	2	1
Shale, drab	3	
Coal, poor	1	3
Shale, arenaceous	6	
Coal		6

	Ft.	In.
Shale	8	
Coal		3
Shale	2	
Coal	1	
Shale	2	
Sandstone, soft, brown	20	
Shale, drab	2	
Coal	1	
Shales, brownish and buff	22	
Sandstone	10	
Coal		8
Shales, black and brownish	16	
Sandstone, soft, gray	4	
Shale, arenaceous, brown	4	
Coal, fairly good	2	
Sandstone, hard, grayish white	18	
Shale and sandstones	16	
Sandstone, gray, soft	12	
Sandstone, yellowish	35	
Sandstone, thin bedded, gray	75	
Shale, drab	5	
Sandstone, soft gray	5	
Shale, drab, arenaceous	25	
Sandstone, base of Mesaverde	50	
Transition, Mancos beds.		
	361	5

Locality 15: On the Mesaverde outcrop near Senorita a local copper company has put down a shaft to a depth of 20 feet on a coal bed 6 feet thick. This bed dips 70° E. and is associated with rocks in an overturned monocline adjacent to the Sierra Nacimiento. In immediate contact with the coal on either side is brown carbonaceous shale. This shaft is known as the Senorita mine, but up to the present time no coal has been taken out. The shaft was sunk several years ago and at present is partly filled with débris. The coal is reported to have given satisfaction, but its development depended on local copper mines which have been closed.

Locality 16: In the eastern part of T. 18 N., R. 5 W., a workable coal bed is exposed at the end of Chacra Mesa. The following is a section of this bed, in rocks dipping 3° N.

Section of coal bed at locality 16, T. 18 N., R. 5 W.

	Ft.	In.
Sandstone, gray	10	
Shale	1	
Coal	3	2
Shale, brown	20	
	34	2

Locality 17: In the northern part of T. 19 N., R. 8 W., the following section was measured:

Section of coal bed at locality 17, T. 19 N., R. 8 W.

	Ft.	In.
Shale, dark	3	
Coal, bony	1	
Coal	3	1
Shale, brown, carbonaceous	3	1
	10	2

Locality 18: In the southern part of T. 20 N., R. 8 W., the following section was measured:

Section of coal bed at locality 18, T. 20 N., R. 8 W.

	Ft.	In.
Sandstone, massive	50	
Shale, drab	5	
Coal		6
Shale, dark, carbonaceous	4	
Shale, dark	4	
Coal and bone	1	10
Coal	1	11
Coal and bone		3
	67	6

The coal beds of the field under discussion, as well as of the entire San Juan region, are very irregular as to thickness and horizontal extension. The beds are lenticular, and appear at different horizons in different localities. The upper and lower portions of the formation bear the important coal beds, the intervening strata being barren.

The following is a general section of the Mesaverde formation measured from the mouth of Arroyo Torreones, in T. 16 N., R. 4 W., northward to the east end of Chacra Mesa:

Section of Mesaverde formation from Arroyo Torreones to Chacra Mesa.

	Ft.	In.
Sandstone, massive, brown	50	
Sandstone and shale	125	
Shale and some sandstone	120	
Sandstone, massive, brown	25	
Shale, thin streaks of coal	20	
Sandstone, gray	20	
Shale, drab	10	
Sandstone, gray	10	
Shale	125	
Sandstone, brown	3	
Shale, drab	30	
Sandstone, tan-colored	20	
Shale, carbonaceous	16	
Coal	1	6

	Ft.	in.
Shale, carbonaceous	6	
Coal		6
Shale	5	
Sandstone, gray	8	
Shale	3	
Coal	1	
Shale	1	8
Coal	1	2
Shale	4	
Sandstone, massive, gray	10	
Shale, hard	1	
Coal	3	2
Shale, brown	20	
Shale and thin sandstone	50	
Coal	1	8
Shale	10	
Shale and sandstone	200	
Sandstone, massive, nodular	10	
Shale	6	
Sandstone, brown	8	
Shale, drab	6	
Sandstone, massive, brown	12	
Shale	15	
Sandstone, massive	2	6
Shale and thin sandstone	15	
Coal and bone	1	
Shale	3	
Sandstone, massive, brown	10	
Shale and thin sandstone	6	
Sandstone, massive	15	
Shale, thin streaks of coal	50	
Coal	2	9
Shale	10	
Sandstone, brown	3	
Shale, drab	15	
Sandstone, brown, calcareous	2	
Shale	10	
Coal	1	1
Shale and thin sandstone	150	
Coal	3	
Shale and thin sandstone	50	
Sandstone	20	
	1,328	

"LARAMIE" COAL BEDS.

Coal beds in the "Laramie" formation are known in the vicinity of Raton Spring and to the northwest, along the north side of Chaco Canyon. Very little is known of the quality of the "Laramie" coals in this portion of the San Juan Basin. The beds are undeveloped and little prospected on account of their long distance from any railroad. The coal appears to be much like the "Laramie" coal elsewhere in the basin.[a]

Locality 19: In the eastern part of T. 21 N., R. 8 W., two coal beds were observed in the "Laramie" where the unconformably overlying Puerco shale has been partly removed by erosion. The lower bed is apparently about 7 feet thick and a 5-foot bed is exposed a short distance above it. The character of the "Laramie" strata above and below these beds could not be made out because they are obscured by the Puerco. It is probable that the two beds are identical with the lower and middle of three beds near Raton Spring.

In the northeastern part of T. 19 N., R. 6 W., and the adjacent area there are three coal beds, as shown in the following general section:

Section in Raton Spring and vicinity, T. 19 N., R. 6 W.

	Ft.	In.
Sandstone, gray	3	
Shale, carbonaceous	1	
Coal	2	2
Shale, carbonaceous	3	
Shale, drab	25	
Shale, carbonaceous	1	
Coal		6
Shale		3
Coal	3	7
Shale, dark	3	
Shale, gray, sandy	15	
Sandstone, grayish	3	
Shale, drab	15	
Coal streak		
Shale, carbonaceous	3	
Coal	1	
Shale, sandy		2
Coal	2	
Shale	3	
	84	8

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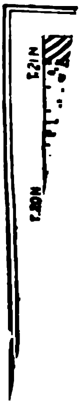
[a] See Schrader, F. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 241-258, Shaler, M. K., Bull. U. S. Geol. Survey No. 316, 1907, pp. 376-426.

U. S.



QUALITY OF THE COAL.

Little is known of the actual fuel value of the coal in this field. This section of New Mexico is very sparsely populated and at a considerable distance from lines of transportation, so that the coal beds have not been prospected; hence fresh samples were not available for analyses. As the southern part of the field is a district of former volcanic disturbance some metamorphism of the coal is to be expected. A considerable area of coal rocks between San Mateo and the Puerco Valley is concealed by the lava flow forming Mount Taylor Mesa. It is impossible, without drilling, to determine the character of the coal beneath this lava. The immense heat which must have attended these eruptions from Mount Taylor and the surrounding vents probably had some effect on the coal beds now covered by the lava, which at some points reaches a thickness of 200 feet. The lava lies directly on the coal along the truncated boundaries of the inclined beds, but the vertical distance between ranges up to 600 feet at the north edge of the mesa.

The coal of this district is of approximately the same geologic age as that at Gallup. At that place the coal is noncoking and has a fuel value of 10,000 to 12,000 British thermal units on air-dried samples. So far as known to the writer, all the coal of the field discussed in this paper outside of the lava-covered area is similar to the coal of the Gallup district.

PETROLEUM AND NATURAL GAS.

GEOLOGY AND OIL PROSPECTS OF THE RENO REGION, NEVADA.

By Robert Anderson.

INTRODUCTION.

During the last few years much interest has been aroused in Nevada over the question whether petroleum may be obtained from any of the geologic formations of the State. Up to the present time no paying quantity of oil has been found here, but prospecting is going on at a number of different localities in regions of diverse geologic character.

In November, 1908, the writer made an examination of the area around Reno, in western Nevada, where a well had been for some months in process of drilling. The present paper discusses the geology of the region, especially the supposed oil-bearing beds, and outlines the conclusions reached regarding the possibility of the occurrence of petroleum.

The examination of the Truckee formation in the region discussed in this paper has resulted in the conclusion that it contains no paying quantity of petroleum, if any at all. Reasons for this conclusion will be found at the end of the paper.

SITUATION AND TOPOGRAPHY.

The Reno region is situated at the western edge of Nevada and of the Great Basin, near the eastern part of the Sierra Nevada, where Truckee River flows from the mountains into the open plain of the Truckee Meadows. The territory examined lies in the foothills within a few miles of the city of Reno, along the boundary line between the Reno and Carson quadrangles, as mapped by the United States Geological Survey.

The level floor of the Truckee Meadows extends to the east and southeast of Reno, and is bounded within a few miles on all sides by hills and mountains, except at the narrow canyon that gives outlet to Truckee River through the Virginia Range on the east. The elevation of the meadows is 4,500 feet above the sea. To the west the plain narrows in the vicinity of Reno, and is continued upward toward the base of the Sierra Nevada by the valley of the Truckee. This valley is bordered on the north and south by several interrupted terraces at different levels and by foothill ridges that slope with gentle incline up to the foot of the steep, rough faces of the mountain blocks that form high spurs of the Sierra Nevada. This summit slope of the hills is itself an old terrace, being the highest and most widespread one. It begins at an elevation between 300 and 400 feet above the river, and its upper limit is in some places as much as 800 feet above the valley. The mountains rise several thousand feet higher, the Peavine Mountain block to the north and the Carson Range block to the south of Truckee River.

GEOLOGY.

GENERAL OUTLINE.

The geologic column of the Reno region is noteworthy for its incompleteness, most of the periods of past time being unrepresented in the rocks. Portions of the Tertiary and Quaternary alone are recorded in unaltered sedimentary beds, and even these do not afford, so far as yet found, evidence of their exact age.

The main topographic divisions of the region correspond to areas of diverse geology. The mountains present the oldest rocks, which are igneous and metamorphic. The terraced foothill belt, with the exception of a thin surface coating of gravel, is formed of upturned middle Tertiary sedimentary beds, the abrupt transition between the gentle ridges and the steep mountains being approximately coincident with the contact between these beds and the older rocks. The valley and lower hill slopes are covered by horizontal sedimentary deposits of much more recent age. In the present connection the middle Tertiary beds are of prime importance.

For a more general account of the geology of this portion of Nevada the reader should consult the reports of the Fortieth Parallel Survey,[a] in which some of the features of the region are discussed, and a recent paper by G. D. Louderback,[b] which is devoted to this region in particular.

THE BED-ROCK COMPLEX.

The oldest rocks in the Reno region are those forming the mass of Peavine Mountain and the axis of the Carson Range. They are described by Louderback in the paper above cited under the designation "Bed-rock complex" as consisting "chiefly of granitic rocks, largely granites (in part granodiorites), with residual masses of more or less metamorphosed sedimentary and igneous rocks into which they were intruded." This complex was classed as Archean by the geologists of the Fortieth Parallel Survey, but is more probably of much later origin, as is stated by Louderback, the metamorphic rocks being Paleozoic or Mesozoic, or both, and the intruding granitic rocks of the same age as those of the Sierra Nevada. There is reason to believe that the complex corresponds to the "Bed-rock series" described by various geologists in the Sierra Nevada. Good exposures of the fresh granite appear in the rocky hills bordering the river valley 5 miles west of Reno.

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[a] Rept. U. S. Geol. Expl. 40th Par., vol. 2, 1877, p. 849; vol. 1, 1878, pp. 412 et seq.

[b] General geological features of the Truckee region east of the Sierra Nevada: Bull. Geol. Soc. America, vol. 18, 1907, pp. 662–669.

TERTIARY VOLCANIC ROCKS.

The rocks overlying the bed-rock complex are lavas and mingled products of volcanic eruptions. They were probably formed during the Tertiary period after a long interval during which the older rocks had formed a land surface in this region. As a consequence of the granite intrusions, the deformation of the older rocks, and the long period of erosion, the volcanic rocks rest upon the bed-rock complex unconformably.

The lava is andesite, varying in mineralogical character from place to place. It is intermingled with locally indurated agglomerate formed of tuff and angular and rounded fragments of lava of all sizes up to huge bowlders. These rocks are well exposed near the head of Alum Creek, about 4 miles southwest of Reno, and form the entire face of the Carson block to the northwest and to the south from that point. Basalt of late Tertiary or Pleistocene age, dating from a period after that in which the Truckee formation, next to be described, was deposited, occurs about 8 miles up the river west of Reno, but not within the immediate area here described.

TRUCKEE FORMATION.

Occurrence and correlation.—The single terrane of unaltered sedimentary beds in the Reno region that is known certainly to be older than the Quaternary comprises 2,100 feet or more of diatomaceous earth, sand, original and reworked tuff, clay, gravel, and minor lignitic beds. These strata occur in a monocline dipping at medium angle away from the mountains toward the Truckee Meadows. They make up an apparently continuous, conformable succession, which, though it is divided into several zones characterized by a somewhat different grouping of various sediments, may be regarded as one formation. The formation lies upon the andesite, and was built up during the period succeeding that in which the major portion of the andesitic eruptions took place.

The Truckee formation is continuous, though only here and there exposed, over an area of 15 to 20 square miles just west of Reno. It is coextensive with the foothill area for 5 miles west of Reno, for about 2½ miles north and 1 to 2½ miles south of the river. It is continuous in the hills on the west side of the Truckee Meadows south of Reno, and is to be found also in the hills bordering the river valley around Verdi, 10 miles west of Reno; in Spanish Spring Valley, Lemmon Valley, and other basins to the north of the Truckee Meadows; and, according to Louderback, in the summit region of the Virginia Range south of the point where that range is cut by Truckee River.

These beds were correlated by Clarence King[a] with similar deposits that are widely scattered over the western portion of the Great Basin and were classed together by him under the name Truckee group. He concluded that the beds of this "group" were formed in Miocene time in a vast fresh-water lake which he named Pah Ute Lake. He considered them to be contemporaneous, if not continuous, with the beds of the John Day Valley in Oregon. He described a typical occurrence of them at the north end of the Kawsoh Mountains and the south end of the Montezuma Range, to the west of the Carson and Humboldt Sink, about 50 miles northeast of Reno, where they measured 2,300 feet in thickness. As a whole, he considered the beds to be not less than 4,000 feet thick. Evidence of their age is scanty as yet. They may belong to the late Eocene, the Oligocene, or the Miocene. Similar beds occur in isolated areas in many portions of western Nevada, being exposed chiefly along the margins of the basins. Lindgren[b] has described beds in the mountains across the California line to the west of Reno, which probably belong to the same formation, and which he considers to have been formed as lake deposits. They occupy small areas in the branch valleys of Truckee River, are slightly tilted, and consist of tuff, yellowish sand and clay, thin seams of impure lignite, and brilliant white deposits containing diatoms, but considered by him to be volcanic ash. The description suggests that these beds are very similar to the diatomaceous earth and other sediments of the Truckee formation near Reno. Turner[c] has described a very thick terrane in Esmeralda County, in southwestern Nevada, under the name Esmeralda formation, which the meager evidence obtainable places in the middle Tertiary. He ascribes a lake origin to the formation and suggests that it may be a continuation of the Truckee. Spurr,[d] in giving a general map of the formations of southern and central Nevada, follows this suggested correlation.

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[a] Rept. U. S. Geol. Expl. 40th Par., vol. 1, 1878, p. 412 et seq.

[b] Lindgren, Waldemar, Truckee folio (No. 39), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

[c] Turner, H. W., The Esmeralda formation: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 2, 1900, pp. 191-208.

[d] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. U. S. Geol. Survey No. 208, 1903.

Structure.—The Truckee formation dips away from the mountains at an average angle of at least 20°. The dip varies locally, without any system of variation that has been discovered, from 35° to 12°, but these extremes are rare, the usual dip being between 20° and 27°. Southwest of Reno the beds dip to the northeast, but northwest of the town they dip more to the east or southeast, thus forming a broad syncline or downward warp in the general monocline, with its axis along the valley of Truckee River. West of the mouth of Hunters Creek, however, which is about 4 miles upstream from Reno, the valley appears to diverge to the northwest from the course of this axis. In the region of Verdi, a few miles farther west, the beds dip in the opposite direction—southwestward or westward—so far as observed, and it is therefore probable that they formerly extended in an anticlinal fold over the region between. The anticline is believed to have resulted from a combination of folding and faulting.

Throughout the Reno region the Truckee formation is traversed by an intricate system of small faults with throws of only a few inches or feet. Almost every exposure of the beds displays a number of such faults forming a network of small displacements. The faulting is almost invariably of the normal type, and the hade is usually between 45° and the vertical. Though these faults traverse the strata in all directions and the beds are thrown down variously, it is believed that in most of the faults the hade is in a general westward direction and that there is a considerable resultant downthrow to the west. In consequence, much duplication of the beds is brought about and the thickness of the strata composing the monocline is exaggerated in appearance.

Lithology and thickness.—The best exposures of the Truckee formation in the Reno region are obtainable along the two flumes that follow different contours in the hills south of the river. By means of these and other exposures in the vicinity, a section was obtained from the base of the formation on Hunters Creek to the highest beds exposed, about 2 miles southwest of Reno and one-half mile east of the Washoe Oil and Development Company's well. The different zones appearing in the formation in this section may be described as follows, from the base upward:

Zone A (100 + feet). The pre-Truckee andesite is overlain by a zone of tuff and agglomerate, in which no well-marked stratification or certain indication of its relation to the overlying beds has been found. It is believed to have been deposited subaerially. It may or may not be properly considered as a portion of the Truckee formation.

Zone B (600+ feet). Within 100 or 200 feet above the andesite, definite stratification begins in alternating, fairly thin beds of tuffaceous sand and grit, gravel and clay. Several thin layers of white, impure diatomaceous clay appear. The beds are of many different varieties and are locally variable, and in some of them many ingredients are intermingled. Fine material predominates, but in several there are scattered pebbles reaching a diameter of several inches. The sand is composed chiefly of somewhat rounded crystals of feldspar and ferromagnesian minerals. Some of it has the bluish color common in tuffaceous beds, but the predominating color of this zone is a whitish gray. The color varies, however, with the individual beds and the sand assumes a yellowish cast, especially toward the top. In general, the bedding is well defined, but the banding within the beds is irregular. The sand and pebble layers are in many places cross-bedded. Here and there many impressions of plants, like reeds or rushes, appear in the fine-grained beds.

Zone C (500+ feet). Zone B grades upward into a zone not markedly differentiated from it. The chief difference is that diatomaceous and argillaceous beds increase in quantity and alternate in thin zones with sand. Most of the fine-grained beds are whitish diatomaceous earth like that occurring in zone D but for the most part not so pure. This material occurs here in thin, rather irregular laminæ and is soft and flaky, though fairly compact. It contains numerous elongated flat impressions grouped together thickly and overlying one another which are, with little doubt, marks of reeds or rushes. Locally, there may be found traces of leaves, black carbonaceous specks, and brown lignitic discolorations. A few delicate fragments resembling bones were found in the sand, but they are not certainly bones. The fine-grained layers increase in number toward the top of the zone. Sand, grit, and pebble beds similar to those in the zone below occur, but the brownish-yellow sand predominates and is, in fact, the most abundant type of sand in the formation as a whole. It is a very porous, friable, usually fine sand, with even, subangular grains of differently colored crystals. The pebble beds occur sparingly and the pebbles are not coarse. A few beds of sand are somewhat indurated.

Zone D (500+ feet). Zone C is succeeded by a fairly distinct zone composed almost entirely of white diatomaceous earth or shale, of which the diatom skeletons form the principal constituents. A few thin seams of fine yellow sand, usually hardened by an abundance of iron oxide, appear as mere partings, but the quantity is almost negligible. The diatomaceous earth varies in color from cream to pure white and is dazzlingly bright in strong sunlight. It occurs in pure massive and homogeneous deposits, through which continuous lamination planes are not traceable; in thick beds that are roughly laminated; and in thin beds with sharp partings. The material of the massive beds splits conchoidally in all directions, whereas the more laminated varieties have a somewhat shaly fracture. The earth is compact and coherent, yet porous and soft enough to be easily crushed or cut into any shape. It is so light that it floats on water. The powder that rubs off the surface is smooth and fine like flour, and leaves a similar white dust on the hands. The purest of the material contains no grit whatever, but in much of it a slight amount of the very finest grit may be detected between the teeth. Impressions of marsh plants occur as described in the lower zones, the organic matter being entirely removed or else left only in the shape of a brown stain or thin film of carbonaceous matter. Remains of leaves of deciduous trees have been found sparingly. The cracks and lamination planes in these beds are in places followed by layers of iron oxide.

This diatomaceous earth is almost exactly like the softer varieties of the well-known Monterey shale and the diatomaceous beds of other formations in California. It differs chiefly in the fresh-water instead of marine character of the diatom species that compose it. None of the porcelaneous or flinty beds characteristic of the Monterey and other formations of California have been found here, but some of the beds are sufficiently compact and distinctly bedded to be termed shale.

These beds described as diatomaceous earth no doubt contain considerable fine silt, and some beds include minor quantities of volcanic ash, but as a whole they are unusually pure. Continuous exposures of several hundred feet of the pure-white beds of this zone are afforded by the railroad cut north of Truckee River, about 4 miles west of Reno. There some layers of gritty grayish-white volcanic ash composed of angular needles are interbedded with the white earth and grade into it. The exposures of zone D are excellent on the line of the section along the flume for half a mile or more west of the Washoe Oil and Development Company's well, its contact with the zone above being exposed just north of the well.

Zone E (75+ feet). The beds of zone D are sharply but conformably overlain by a zone composed almost exclusively of coarse and fine yellowish sand, like that of zone C. One bed of coarse sand, about a foot thick, is stained brownish black by iron and manganese oxide, making it look like oil-stained sand. The beds vary from mere laminæ to layers several feet thick and are sharply marked off from one another by banding due to changes in material and texture. There are some clay seams and a few layers of impure diatomaceous earth. In places the sand is roughly aggregated and contains lenses of gravel. A thin layer of impure lignitic cross-bedded material was observed.

Zone F (275+ feet). Zone F is a continuation of beds like those of the zone below, but contains a greater proportion of clay and diatomaceous earth. In general aspect the outcrops present a white or yellowish-gray color, but the individual beds exhibit a variety of shade, texture, and character. The fine-grained beds show all gradations between sand, micaceous gritty and earthy clay, and diatomaceous earth, different varieties being interlaminated. At the base of this zone and at points higher up in it there are minor zones, several feet in thickness, of white diatomaceous earth, usually somewhat gritty and impure.

Zone G (50+ feet). Above zone F the beds cease to be well exposed and the dip is uncertain. Sand like that below is exposed for several hundred feet with an appearance of a low dip, until finally entirely covered up by a thin capping of Quaternary gravel. The highest beds of the Truckee formation exposed in this section are at a point from 1 to 2 miles east of the Washoe Oil and Development Company's well.

The total thickness of the zones described above is 2,100+ feet. The direction along which the section was measured is east-northeast, whereas one taken directly across the strike would trend considerably more to the northeast. It is believed that more duplication of the beds occurs along this line than there would along a line normal to the strike, for the reason that they are probably thrown down more and more toward the west by small faults as the axis of the downfold before mentioned is approached. But it is thought that in any case considerable allowance for such reduplication would have to be made in the estimates of thickness. The apparent thickness of the beds traversed in the section was 3,600 feet. This has been reduced in the above description to 2,100 feet. The amount of reduction proper under such conditions, however, is not measurable, and therefore the thicknesses of the zones as here given are to be considered as only rough estimates of the actual thickness of the beds. They are thought to be conservative. Moreover, there may be a considerable thickness of beds above the highest that were found exposed, which were at the brow of the hills between 200 and 300 feet above and over a mile from the plain of the Truckee Meadows, toward which the beds dip.

The beds of the Truckee formation are by nature variable and in other portions of the Reno region they do not conform exactly to the character displayed in the section described. The basal portion, especially, is variable. The lower part of the formation, 5 miles west of Reno, for instance, where it overlies the granite is composed of roughly aggregated granite and tuffaceous sand, gravel, and breccia, with some layers of fine sand and clay. In the region of the above-described section no granite materials were observed. At the head of the east fork of Alum Creek, about 4 miles southwest of Reno, and in the hills extending from that place toward Reno, the lower portion of the formation contains a larger proportion of diatomaceous earth than was seen in the section described. To take the formation as a whole in the Reno region, it may be said that between one-third and one-half of the total thickness is made up of beds composed largely of diatom remains.

Fossils.—The Truckee formation is poor in fossils by means of which its age may be determined. Impressions of reeds or rushes, a few leaves of deciduous trees, and diatoms are the only remains found at all well preserved in the Reno region. The impressions supposed to be reeds or rushes are very abundant but usually fragmentary and faint. They occur in all parts of the formation in the section above described, especially in the diatomaceous earth, and also in the lignite and diatomaceous beds near Verdi, in Spanish Spring Valley, and elsewhere, being everywhere characteristic of the Truckee. A leaf resembling that of the maple was found in the diatomaceous earth of zone D along the flume about half a mile west of the Washoe Oil and Development Company's well, and other leaf fragments were obtained elsewhere. A small cone resembling a fir cone was brought up in the above-mentioned well from the carbonaceous matter at a depth of 1,540 feet. There are numerous specimens of plant remains in the collection at Stanford University, as was learned through the kindness of Prof. J. P. Smith, which came from tuffaceous beds in the vicinity of Truckee River somewhere "near Reno," the locality not being more definitely specified on the label. The beds are probably part of the Truckee formation. The leaves resemble in a general way those of the birch, service berry (*Amelanchier*), manzanita, and willow. The collection contains one pine-cone impression. According to Professor Smith, the leaves are like the Miocene types of the Sierra Nevada and Pacific coast province, and would favor a middle rather than an early Tertiary age for the beds.

The diatom fauna of the Truckee formation is a rich one and many of the specimens are very well preserved. In the Reno region layers and zones of diatomaceous earth occur throughout the formation, and in its center there is a zone many hundred feet thick composed in large part of the siliceous shells of diatoms. Under the microscope this white earth appears as an almost pure mass of diatom remains. Many different species are recognizable in it, all of freshwater types. Similar enormous deposits of diatomaceous earth are characteristic of the Truckee formation elsewhere.

According to Clarence King, in his description above cited, 46 distinct species of diatoms were found by Dr. C. E. Ehrenberg in specimens of similar diatomaceous earth from Nevada. King reported the finding of fresh-water mollusks in a limestone bed in the middle of the Truckee at the type locality west of the Carson desert. A rhinoceros tooth and leaves were found there also. Fish remains are reported by Louderback from beds of this formation east of the Virginia Range.

Origin.—The Truckee formation was assumed by Clarence King to indicate that a fresh-water sea spread over western Nevada, and even far beyond its limits to the north and south, during middle Tertiary time. A simpler explanation, however, that is believed to be more in accordance with the evidence that has been found may be proposed to account for the presence of these beds in the portion of Nevada around Reno. The abundance of remains of grasslike plants characteristic of a marshy habitat and the occurrence of lignitic layers at different horizons indicate that much of the sediment was laid down on marshy ground where reeds and rushes grew. The broad leaves and the stems of these plants, mingling with the fine sediments that were washed in and with the remains of the diatoms that lived in the water, were preserved in the layers of ooze thus formed, and even helped to build up the deposits. At times these plants accumulated in especial abundance to form peat. The abundance of the diatoms is in accord with this theory of the origin of the deposits, for these organisms are known to be notably prevalent in sheets of shallow fresh water and over marshy tracts. At the present day their skeletons may be found accumulating in such places and forming deposits. The features that have been described, coupled with the local variability and irregularity of stratification of many of the beds, indicate that the greater portion of the terrane was deposited over the surface of a watery plain that may at times have been inundated to form a lake and at other times have been dry.

That the beds were not chiefly formed in a lake is indicated further by the usual lack of the remains of animal organisms such as inhabit lakes, by the absence of changes in the character of the sediments such as would be expected in lake deposits at different distances from the shore, and in general by the shallow-water or surficial rather than deep-water nature of the beds. The character of the materials proves the proximity of the source of supply, and the accumulations of leaves of deciduous trees and other tree remains indicates nearness of the dry land. The manganese and iron oxides permeating many of the sands suggest a bog origin. The cross-bedding and rough intermingling of sediments common in the coarser material give evidence of deposition by streams. Louderback, in his paper before cited, says that the basal beds near Reno "show several alternations of distinct lake sediment and alluvial material or wash each a few feet or yards thick," and concludes that the lake in which he considers the beds to have been deposited fluctuated in areal extent and probably occupied "an interior basin without outlet (at least part of the time) similar to the Quaternary Bonneville or Lahontan."

The principal materials making up the Truckee formation are the innumerable diatom tests and other plant remains, little-worn crystalline grains derived from the erosion of not far distant lava and tuff, grains derived by erosion from the various older rocks, and tuff from the eruption of volcanoes in action at the time the beds were formed. These materials were accumulated through the direct deposition of the organic remains, by means of streams that spread widely over the plain, and by the wind.

It is hard to believe that such a thick series of beds could have been formed continuously over the vast territory of the hypothetical Pah Ute Lake. It would seem that the difficulties of explaining the subsidence of this area so as to accommodate a series so great, the position of a source of supply for sediments such as those of the Truckee formation, the development of the later physical features, and the whereabouts of the enormous quantities of material that would have had to be removed to leave only the present small patches of these beds, not to speak of other questions involved, would preclude the possibility of such a hypothesis. It is more probable that during the general Truckee period conditions more or less similar prevailed in several or many different basins within this broad region, these basins and their bounding ranges being developed in some degree as they are to-day, and that basin deposits were formed in each as they are forming now. The conditions of sedimentation differed chiefly from those of the present in that the moister climate of middle Tertiary time favored the presence of fens and marshes, streams, and temporary lakes. The basins probably underwent a process of gradual subsidence with respect to relatively rising mountain blocks that hemmed them in.

LATER GRAVELS.

The foothills, river terraces, and valley in the Reno region are covered almost everywhere with a mantle of gravel that has been deposited since the tilting and partial removal by erosion of the Truckee formation. They lie nearly if not quite horizontal and represent a relatively recent geologic period, being for the most part Quaternary. No evidence has been obtained, however, bearing on the age of all of these deposits, and late Tertiary beds may be present beneath the valley floor as well as in places at the surface. It is believed that these gravels accumulated during long periods of time through the agency of streams over former valley floors and as alluvial deposits, and that they do not necessarily indicate that lakes occupied the region during certain periods, though it is not improbable that bodies of water existed at times.

Approximately horizontal, stratified gravel deposits having a thickness of at least 50 feet occur at various places in the valley of Truckee River and around the edge of the Truckee Meadows. An excellent exposure occurs on the north side of the valley between 1 and 2 miles west of Reno, where the beds are cut by a normal fault having a throw to the west of 20 to 30 feet.[a] These beds may be either late Tertiary or Pleistocene in age.

The terraced surfaces of the foothills in the Reno region are covered with a variable deposit, only a few feet in thickness, of coarse and roughly aggregated gravel with rounded and angular fragments, sand, and some clay. The gravel is full of bowlders of all shapes which range in diameter up to several feet and which weather out and strew the surface. In places the deposit is very thin, and allows the underlying Truckee formation to appear; elsewhere it has a thickness of 15 feet or more. In the higher hills a surface talus of angular blocks appears here and there.

The lower terraces are capped by irregular gravel deposits of more recent age than the main portion of the deposits already described. In some places the surface is literally one mass of huge loose bowlders.

ECONOMIC DEVELOPMENTS.

The opinion has spread among various persons interested in the Reno region that petroleum will be obtained from the strata in this vicinity. Accordingly, a number of claims have been taken up and companies have been formed with a view to prospecting for the oil. One of these, the Washoe Oil and Development Company, started drilling a well in August, 1907. In November, 1908, when the well was visited by the writer, it had reached a depth of 1,890 feet, but drilling had been suspended, temporarily at least, at that time. The well is situated on the brow of one of the ridges of the foothills, a little over 2 miles southwest of Reno, a mile south of Truckee River, and at an elevation of about 300 feet above it, in the SE. ¼ sec. 21, T. 19 N., R. 19 E. (Mount Diablo base line and meridian). The following is the log of the well, as furnished by the company:

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[a] See photograph and description of interesting features in the paper by G. D. Louderback (Bull. Geol. Soc. America, vol. 18, 1907, pp. 662-669).

Log of well No. 1, Washoe Oil and Development Company.

	Feet.
Conglomerate	10
Sand	105
Blue chalky shale	140
Chalky shale	205
Blue chalky shale (water at 225 feet)	230
Blue shale	280
Caving blue shale	340
Shale	370
Blue shale	540
Sticky blue shale	570
Blue shale	660
Blue shale, a little lighter	730
Blue shale	790
Blue shale, lighter	810
Blue shale	830
Hard shale	840
Blue shale	945
Light-blue shale	970
Caving blue shale	980
Blue shale	1,135
Brown shale	1,173
Sand and hot water (water rises within 200 feet of surface)	1,200
Sticky brown shale	1,208
Brown shale	1,230
Blue shale and a little sand, with water	1,250
Blue shale, showing a little oil	1,270
Water sand	1,300
Brown sand and shale	1,325
Shale and conglomerate, some very hard	1,350
Sticky blue shale	1,365
Brown shale, with a little sand	1,370
Brown shale, with hard layers	1,375
Blue shale	1,385
Brown shale	1,407
Blue shale	1,410
Brown shale, with a little sticky blue shale	1,447
Blue shale	1,460
Dry sand	1,470
Blue shale	1,475
Brown shale	1,515
Sand, with water	1,520
Blue shale	1,530
Brown shale	1,540
Streaks of coal	1,545
Brown shale, with streaks of sand and blue shale, caving and running	1,600
Brown shale	1,695
Blue shale and a little sand, with water and a little oil	1,710
Blue shale	1,890

The well is very near the contact between zones D and E in the geologic section before described. For the first 10 feet or so the well was drilled through the Quaternary gravel at the surface; the next 95 feet mentioned in the log are thought to be the basal beds of zone E, and the "shale" beds below that are the diatomaceous earth of zone D. The well probably does not penetrate any beds lower than zone C, and considering the supposed duplication of the strata by faulting, it might doubtless go much farther down without reaching the base of the formation. Of the oil stated in the log to have been discovered in the drilling, the present writer has no personal knowledge. No gas is struck in the well, except possibly some hydrogen sulphide. A sample of the mud from the bottom of the well was brought up by the bailer at the time of the writer's visit. It was a fine-grained dark-gray gritty clay, full of mica particles. Though the bailer was brought up through cold water, its contents were still steaming and heated to over 90° F., indicating that the temperature at the bottom was considerably greater.

The operations connected with the drilling were for the most part not difficult. The strata were penetrated easily and only an occasional very thin hard layer was encountered. The 12½-inch and 10-inch casing was inserted at once after drilling, no underreaming being necessary. Some difficulty was experienced with caving sand and mud and in shutting off the water. An average of 25 to 30 feet was drilled through each twenty-four hours.

CONCLUSIONS AS TO THE OCCURRENCE OR NON-OCCURRENCE OF PETROLEUM.

The question whether or not oil will be found in the Reno region may be limited to the Truckee formation, for that formation alone affords strata in which oil might be reasonably sought in appreciable quantity. From the character of these strata such search is not entirely without reason. The fact that the beds are so rich in diatom remains suggests the possibility that oil might have originated in them as it is believed to have done in some of the diatomaceous beds of California, the diatoms being the supposed source, at least in part. There is, however, no ground for the popular misconceptions that the beds in Nevada are the same as the oil-bearing strata in California and that a continuous petroliferous belt is traceable from the Bakersfield region northward through Nevada. As a matter of fact, no such belt and no close relationship between the formations exists. The beds in Nevada were deposited in fresh water and upon the land, whereas the oil-bearing strata in California were laid down in the sea. The questions as to oil occurrence must be treated independently in the two provinces. Furthermore, the beds in different parts of Nevada are of different age and origin and each locality requires to be treated on its own merits. The conclusions presented below apply to the Reno region only. They are not claimed to be more than the individual opinion of an unbiased observer.

It is believed that the Truckee formation does not contain petroleum in paying quantities, if at all. The following are the principal reasons for this conclusion:

(*a*) No indication of the presence of oil has been discovered in the beds at the surface, although they are tilted and the succession is exposed as a whole in such a way that some of the oil could hardly fail to escape to the surface and leave a trace, if any were present. Moreover, the completely permeating system of small faults would furnish further avenues of escape. The supposed indications of oil that have been reported by previous observers are iron, manganese, and vegetable stains in certain strata and on the surface of standing pools of water in the vicinity.

(*b*) The structure of the beds is that of a monocline of considerable dip, at the base of which the oldest beds of the formation are exposed overlying andesite and older rocks of the mountains. A large amount of the formation that was originally deposited and upheaved has been removed by erosion, including the upward fold of the beds that probably once arched over toward the west into the southwestward-dipping strata of the Verdi region. That fold, even if imperfect, would most probably have contained the greatest concentration of the oil if any had been present.

(*c*) The monoclinal structure, the truncated and intricately faulted condition of the strata, and their general softness and porosity would favor diffusion and escape of the oil rather than its accumulation in large quantities if any were present.

No definite reasons can be given for the failure of the diatomaceous beds of the Truckee formation to produce petroleum, while the diatom content of the original petroliferous formations in California is thought to have been the source of much of the oil there. Some persons have expressed the opinion that oil is never produced in fresh-water beds. The reason for its absence in this region is probably not to be sought, however, in the inability of fresh-water organisms to produce oil, but rather in the manner in which the beds were laid down and the conditions to which they were subjected after their deposition. The diatomaceous beds of the Truckee are thought to have been formed in marshes and shallow bodies of water, the nearness of the sediments to the surface causing them to be exposed to conditions favoring decomposition and escape of the organic matter they contained. The manner of deposition of the marine beds in California, on the other hand, must have been very different, owing to the depth of burial of the organisms, the possibly greater rapidity of burial, and the chemical constitution of the sea water. Moreover, the partial alteration of the beds in California through pressure, heat, and other causes may have furthered the process of distillation of the oil, whereas the soft beds of the Truckee formation have suffered little change.

TWO AREAS OF OIL PROSPECTING IN LYON COUNTY, WESTERN NEVADA.

By ROBERT ANDERSON.

INTRODUCTION.

One well is being drilled and considerable prospecting for oil is going on in Lyon County, western Nevada, in the valleys adjacent to Walker River. In November, 1908, two days were spent by the writer in examining the portions of this county in which interest centers, namely, the region east of Wabuska near the great northerly bend of Walker River and the region of Smiths Valley north of Wellington. These regions are included in the Wabuska and Wellington quadrangles as mapped by the United States Geological Survey. The purpose of this paper is to outline their physical features[a] and give some details and conclusions regarding the oil prospects.

REGION EAST OF WABUSKA.

The examination was confined chiefly to the basin-like valley in which the Yerington Oil and Gas Company is drilling a well, 7 to 10 miles east of Wabuska and north of the bend of Walker River. This valley is fairly typical of a number of similar basins that form elbows in the valley of the river. The basin is surrounded by mountains formed of andesite and volcanic agglomerate, fringed with a superficial deposit of incoherent lake sediments along an old terrace level of Lake Lahontan. The basin has a fairly level floor with a surface covering of fine sand and clay. Along the river there are exposures of 20 feet or more of horizontally stratified fine light sand and sandy clay, some of which is cross-bedded. The age of this material is probably Quaternary. These unconsolidated deposits, mingled with coarser fragmentary matter, form the floor of the valley. The fact that knolls of the lava which forms the foundation of the valley protrude above the floor of the basin, in places very near the river, points to the conclusion that the sediments filling the basin nowhere exceed a few hundred feet in depth. Such being the geologic character of the region, it doubtless contains nothing to warrant the expenditure of money in the search for petroleum, there being no strata that might be expected to yield an appreciable quantity of oil.

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[a] Some features of the geology of this portion of Nevada have been touched upon in the following publications:

Russell, I. C., Geological history of Lake Lahontan, a Quaternary lake of northwestern Nevada: Mon. U. S. Geol. Survey, vol. 11, 1885.

Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: Bull. U. S. Geol. Survey No. 208, 1903.

Smith, D. T., The geology of the upper region of the main Walker River, Nevada: Bull. Dept. Geology Univ. California, vol. 4, No. 1, 1904, pp. 1-32.

Those interested in the drilling operations in this region state that they obtain oil by the chloroform test from the dirt and from the "shale." The lava in the hillocks that rise above the surface of the basin, as above mentioned, has in places a marked platy cleavage and has been taken to be shale. The following log of the well which is being drilled in the center of the basin was furnished November 12, 1908, by the Yerington Oil and Gas Company:

Log of Yerington Oil and Gas Company's well east of Wabuska, Nev.

	Feet.
Sand and water	40
Blue clay	60
Sand	65
Sand and clay	130
White sand and water	140
Clay	150
Caving sand	240
"Porphyry white" (?)	248
Black rock	262

The hard dark rock at the bottom through which the drill had already penetrated 14 feet, is a porphyritic igneous rock which there is every reason to believe is in place.

SMITHS VALLEY.

Smiths Valley, which is situated in the southeastern arm of Lyon County on the border of Douglas County, is typical of the intermontane basins of Nevada. It is a deep, elongated valley several miles wide between two north and south mountain ranges, the Pine Nut Range on the west and the Singatse[a] Range on the east. The latter swings around the north end of the valley at the mining camp named Buckskin and converges with the Pine Nut Range, narrowing the valley to a defile that leads up to a low pass at its head. The valley opens out somewhat on the southeast toward Wellington, where it is crossed by Walker River, which comes out of a deep canyon at the south end of the Pine Nut Range and flows through a gap in the Singatse Range on the east.

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[a] According to Dwight T. Smith, in the paper above cited, this has been found to be the Indian name of the range. In the bulletin by Spurr it was referred to as the "Smith Valley Range."

The Pine Nut Range presents an abrupt escarpment toward Smiths Valley all along its straight eastern flank. The range is with little doubt a fault block uplifted along this scarp. No foothills intervene between mountain and plain, but the sharp angle between them is softened by fairly steep slopes of talus and alluvial fan deposits. The range is high and massive. It is composed chiefly of granitic and porphyritic igneous rocks, to judge from the débris deposits at the base.

The Singatse Range, on the east side of the valley, is of very different character. It is comparatively low, slopes more gently from the valley, and has an irregularly broken topography and in places pinnacled summits. It is formed chiefly of much-altered limestone intruded by granite and rhyolite and capped with andesite.

The valley floor is remarkably level except where it is encroached upon at the sides by alluvial wash from the mountains and low bluffs of horizontal sedimentary beds. The northern portion of the valley is an inclosed basin, separated by a low rise of ground from the southern portion, which is traversed by Walker River. The drainage of this northern part collects in its center and the lowest portion of the floor is usually somewhat marshy and at times covered with a shallow sheet of water.

On the west side of this basin, at the very foot of the Pine Nut Range, there is a large spring of hot water called Hinds Hot Springs. The water is very pure and leaves no deposit where it issues from the coarse granitic débris at the mountain base. Small streams flow out from it over the meadow. Within a few hundred feet south of the spring cool sulphur water issues from the base of the range and other springs occur elsewhere along the foot. These springs give additional evidence that the east face of the range is a zone of fracturing and faulting.

At numerous places in the valley springs appear near the outer extremities of the alluvial fans. Well-defined stream courses entering the valley are rare and the drainage from the mountains reaches the plain through or under the fans. These springs are apt to be marked by small mounds, probably the result of accumulating vegetation and the retention of wind-blown material at these points.

The deposits that are forming on the surface of the floor are mostly fine grained. At several places exposures of Quaternary sand deposits reveal a considerable admixture of manganese oxide, which probably indicates that the valley was marshy in parts when they were formed, as it is to-day. These black deposits have been mistaken by some person for asphalt. A constant stream of gas issues from the center of the valley floor at one point. The gas burns readily and has been taken as another indication of the presence of oil, but it is probably only a variety of marsh gas.

On the east side of the Smiths Valley basin low bluffs rise above the floor at the edge of a wide terrace or plateau that occupies this side of the valley. The terrace is formed of apparently horizontal strata of light-colored unconsolidated sand and clay, of which a thickness of at least 40 feet is exposed in the bluffs. These beds doubtless underlie the valley floor, having originated as a basin filling in late Tertiary or early Quaternary time. A lake may or may not have occupied the valley at the time of their deposition. It is probable that part of the beds at least represent deposits over the valley floor when it was marshy, similar to deposits that are forming now. According to Russell, Lake Lahontan did not extend into Smiths Valley.

The material of these beds is mostly of fine grain and the stratification massive. Fine sandy clay of light straw color predominates. It contains a great abundance of well-preserved diatom remains and also many small impressions and filaments of vegetable origin. There are also a few remains like those of marsh grasses. Fragments of fossil bones and teeth of large land mammals occur in the sand at the surface of the terrace, having probably weathered out of the beds, but nothing identifiable was found.

It is not known what depth is reached by the sedimentary beds just described. That they have, together with the surface deposits, a thickness in this basin of several hundred feet is very probable. According to Dwight T. Smith in the paper above cited, a thickness of a few hundred feet of these beds is exposed where Walker River cuts across Smiths Valley. The evidences of comparatively recent movements in this region favor the conclusion that the configuration of the basin was determined at no very distant period, geologically speaking, and that the volcanic rocks or older bed-rock series of the original floor underlie the deposits of the basin filling at a depth of not many hundred feet.

The physical features and geologic character of the region are not such as to favor its selection as a possible petroleum producer, and no indications have been found to lend color to the view that oil is present.

ANALYSES OF CRUDE PETROLEUM FROM OKLAHOMA AND KANSAS.

By D. T. DAY.

As part of a systematic examination by the same methods of analysis for all varieties of petroleum in the United States, a study has been made of the petroleums of Oklahoma and Kansas, and the preliminary results are given in the tables below.

These samples were collected in March and April, 1908, by J. P. Dunlop. For this purpose Mr. Dunlop was provided with cans which were soldered immediately so as to prevent all chance of evaporation. One gallon was uniformly taken when the sample was collected at the well, and 5-gallon samples were taken from the pipe lines in order to get a large representative sample from each distinct field. The samples were expressed to the Washington laboratory, where the analyses were made.

A set of very delicate specific-gravity spindles was made especially for this investigation, by C. Tagliabue & Sons. The samples were brought to a temperature of 60° in a cylinder cooled in a water bath. The specific gravity was then taken, and the tables show also the conversion of this figure into degrees Baumé. The samples were then distilled by Engler's method as modified by Ubbelohde. Thus 100 cubic centimeters of the crude oil, measured at 60°, were delivered by a pipette into a distilling bulb holding about 125 cubic centimeters. The dimensions of this bulb are those prescribed by Engler. The thermometer used was a nitrogen thermometer reading to 550° C., which had been carefully standardized by the Bureau of Standards. The condenser tube, as prescribed by Engler, was 75 cubic centimeters long and had an inclination of 75°. The point of initial boiling was taken when the first drop of oil fell from the condenser tube into the receiving flask. To avoid loss by evaporation the condenser tube fitted into the graduated receiving flask, which was provided with a stopcock to draw off the oil at 150° and again at 300°. Note was also taken of the proportions boiling within each range of 25°, but these details are not published in the tables given herewith. The fraction between the initial boiling point and 150°, constituting the gasoline fraction, and the fraction between 150° and 300°, constituting the kerosene fraction, were examined as to specific gravity with a picnometer. The residuum was weighed as soon as cool; then its specific gravity was taken in the usual way and the volume calculated. As will be noted, the total thus obtained for the different fractions includes the sum of all variations in the determinations. This total for many samples slightly exceeds 100 per cent, but for a greater number is considerably below that amount, owing to the presence of water—in fact, the percentage of water is thus rather clearly indicated.

The method of Kramer and Bottcher was used for determining the unsaturated hydrocarbons present in the crude oil and in the distillate between 150° and 300°. The amount of gasoline was in many samples too small for systematic determination of the percentage of unsaturated hydrocarbons in it. The method consists in shaking 25 cubic centimeters of the crude petroleum with 25 cubic centimeters of sulphuric acid of specific gravity 1.83, corresponding to ordinary pure sulphuric acid, about the equivalent of that used in petroleum refining. The acid and oil are shaken in a small flask with a long neck, the neck holding 25 cubic centimeters. The flask is then filled with strong sulphuric acid until the oil which remains uncombined with the acid can be measured in the neck of the flask. The loss in volume between the original 25 cubic centimeters and the oil which remains undissolved by sulphuric acid is taken to represent the unsaturated hydrocarbons.

Paraffin wax was determined by the Engler-Holde method, two parts of absolute alcohol and one part of absolute ether being used as the solvent, from which the paraffin wax is precipitated on cooling to −20° C. The asphalt was determined by Holde's method, by weighing off 1 gram of residuum and shaking this with 40 cubic centimeters of gasoline which was free from unsaturated hydrocarbons and which boiled between 65° and 95° C. After shaking this is allowed to stand for forty-eight hours and the precipitated asphalt is dissolved in benzol, dried at 105°, and weighed.

Without any detailed discussion of the results, which are given clearly enough in the following tables, it is hoped that these analyses will be of considerable use to the producers and the geologic students of the individual pools. They will be supplemented later by determinations of viscosity of the crude oils and of percentage of sulphur and a detailed examination of the distillates, including further study of the nature of the unsaturated hydrocarbons. The main purpose of the examination, however, is to afford a comparison of the oils of this region with the oils from other parts of the United States.

Analyses of crude

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Tulsa County.
35	Well	Mar. 27	80	1	J. I. Yorgee lease, Robt. Galbreath, Tulsa.	3	638	Red Fork pool
36	do	do	80	1	do	5	601	do
37	Leader pipe	do	80	1	Van Yorgee lease, Robt. Galbreath, Tulsa.	1-7	1,240	do
38	Well	do	80	1	Missouri Lincoln Trust Co. lease, L. E. Mallory & Son, Tulsa.	1	1,200	do
39	Pipe line	do	80	5	Pump station at Red Fork, Prairie Oil and Gas Co., Independence, Kans.			do
								Creek County.
49	Pipe line	Mar. 28	60	....	Prairie Oil and Gas Co., Tulsa, Bird Creek district.			Bird Creek and Skiatook pools.
50	Well	Apr. 1	55	1	N Chisholm lease, Creek and Indiana Investment Co., Sperry.	1	1,420	do
51	do	do	55	1	do	4	1,200	do
52	do	do	55	1	Smith lease, Shawnee Oil Co., Sperry.	1	1,408	Skiatook pool
53	do	do	55	1	do	4	1,412	do
54	do	do	55	1	Chisholm lease, Shawnee Oil Co., Sperry.	2	1,466	do
40	do	Mar. 28	60	1	Grace Berryhill lease, Oklahoma State Oil Co., Kiefer.	9-13	1,500	Glenn pool
41	do	do	50	1	Pittman farm, sec. 7 T. 17 N., R. 12, Argue & Compton, Tulsa.	11	1,500	do
42	Pipe line	do	50	5	Pump station, Prairie Oil and Gas Co., Kiefer.			do
43	Well	do	60	1	Thos. Berryhill lease, Indiana Oil and Gas Co., Kiefer.	7	1,518	do
44	do	do	60	1	Wm. Berryhill lease, Indiana Oil and Gas Co., Kiefer.	15	1,529	do
45	do	do	60	1	W. B. Self lease, Prairie Oil and Gas Co., Tulsa.	23	1,523	do
46	do	do	60	1	do	7	1,553	do
48	do	do	60	1	Corndoffer lease, sec. 18, T. 16, R. 12, Swasey Oil Co., Fort Worth, Tex.	1	2,340	Mounds pool
								Okmulgee County.
55	Settling tank	Apr. 2	50	5	Prairie Oil and Gas Co., Morris.			Morris pool
56	Well	do	50	1	Meridian lease, Brown Oil and Gas Co., Morris.	1	1,600	do
57	do	do	50	1	do	4	1,600	do
58	do	do	55	1	Buchanan lease, Burns & Caton, Morris.	1	1,680	Bald Hill pool
59	do	do	55	1	J. W. Buchanan lease, J. Harmon, Morris.	1	1,703	do
								Muskogee County.
60	Well	Apr. 3	55	1	Evans lease, Julia Oil Co., Muskogee.	1	1,553	Muskogee pool. new field.
61	do	do	55	1	do	3	1,473	do
62	do	do	55	1	K. Stevens lease, Success Oil and Gas Co., Muskogee.	2	1,558	do
63	do	do	55	1	J. W. Siebold lease, Success Oil and Gas Co., Muskogee.	1	1,574	do
64	do	do	65	1	Fort Worth Development Co. lease, of Richmond Development Co., Muskogee.	1	1,702	do
65	do	do	65	1	G. W. Sadler lease, Huckleberry & Co., Muskogee.	3	1,735	do
69	Pipe-line tank	Apr. 4	70	5	Prairie Oil and Gas Co., Muskogee.			do

petroleum from Oklahoma.

Physical properties.			Distillation by Engler's method.								Unsaturated hydrocarbons.		Paraffin (per cent).	Asphalt (per cent).
Gravity at 60° F.		Color.	Begins to boil at (°C.).	By volume.							Crude (per cent).	150° to 300° (per cent).		
				To 150° C.		150° to 300° C.		Residuum.		Total (cubic centimeters).				
Specific.	Degrees Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.					
0.8368	37.3	Green.......	88	15.0	0.7195	36.0	0.7945	48.5	0.9073	99.5	22.4	....	2.60	0.0
.8323	38.2	Dark green..	93	9.0	.7220	40.5	.7814	48.5	.9038	98.0	17.6	1	4.39	.0
.8413	36.4	.....do.......	90	14.0	.7352	37.0	.7992	48.9	.8855	99.9	22.4	2	6.37	.05
.8358	37.5	Black.......	97	8.0	.7268	44.5	.7882	47.0	.9021	99.5	14.4	3	3.92	.35
.8594	32.9	.....do.......	110	4.0	.7430	38.0	.7948	55.8	.9103	97.8	18.4	1	4.88	.15
.8626	32.3	Dark green..	120	2.0	....	37.5	.8070	60.6	.9003	100.1	29.2	6	7.30	.28
.8495	34.8	.....do.......	100	7.0	.7380	38.5	.8018	52.8	.9021	98.3	29.2	9	2.87	.62
.8563	33.5	.....do.......	122	Trace.	....	40.5	.8030	57.0	.9021	97.5	14.0	11	8.41	.42
.8480	35.1	.....do.......	95	6.0	.7348	37.0	.7898	54.9	.9032	97.9	14.8	7	7.35	.23
.8439	35.9	.....do.......	98	5.0	.7440	36.0	.7858	58.8	.8997	99.8	12.8	10	9.74	.50
.8328	38.1	.....do.......	68	11.0	.7142	32.5	.7968	51.8	.8974	93.3	13.2	10	6.65	.14
.8459	35.5	Black.......	112	7.5	.7464	42.0	.7980	50.0	.9061	99.5	21.2	6	5.41	.11
.8459	35.5	.....do.......	105	8.5	.7566	42.0	.8001	49.9	.9032	100.4	22.8	7	6.98	.45
.8464	35.4	.....do.......	100	4.5	....	46.0	.7942	49.9	.9032	100.4	27.6	9	5.99	.24
.8439	35.9	.....do.......	105	8.0	.7508	44.5	.8008	48.0	.9091	100.5	20.8	6	7.53	.90
.8333	38.0	.....do.......	80	11.5	.7260	43.5	.7964	45.3	.9079	100.3	21.6	4	11.46	.35
.8373	37.2	.....do.......	94	10.0	.7328	41.0	.7968	47.6	.9021	98.6	16.8	5	3.12	.21
.8424	36.2	.....do.......	98	10.0	.7402	42.5	.7990	47.6	.9079	100.1	26.4	6	9.70	.51
.8631	32.2	Bright green.	175	....	....	38.5	.8126	59.9	.8992	98.4	12.4	4	8.44	.62
.8450	35.5	Light green..	112	3.0	....	34.0	.7924	62.1	.8866	99.1	10.0	1	11.90	.0
.8383	37.0	Dark green..	82	10.0	.7260	30.0	.7988	57.1	.8861	97.1	13.6	3	9.46	.0
.8403	36.6	Green.......	75	13.0	.7338	31.0	.8008	56.4	.8895	100.4	13.2	8	6.75	.10
.8531	34.1	Dark green..	110	5.5	.7515	36.0	.8018	58.0	.9003	99.5	20.0	8	3.43	.15
.8578	33.2	.....do.......	131	1.5	....	35.5	.8096	62.4	.8992	99.4	16.4	3	5.70	.76
.8328	38.1	Green.......	97	11.0	.7332	36.0	.7960	52.8	.8866	99.8	15.2	4	7.64	.0
.8264	39.4	.....do.......	83	11.0	.7218	36.0	.7976	51.4	.8855	98.4	16.8	5	6.03	.0
.8314	38.4	.....do.......	93	12.0	.7298	38.0	.7984	50.3	.8861	100.3	15.2	3	2.24	.0
.8343	37.8	.....do.......	90	7.0	.7316	40.0	.7876	52.4	.8861	99.4	16.8	2	1.24	.0
.8333	38.0	.....do.......	90	11.0	.7090	37.0	.7986	51.2	.8861	99.2	16.4	8	1.52	.0
.8348	37.7	.....do.......	98	5.0	.7410	40.0	.7828	54.6	.8855	99.6	16.0	4	6.96	.0
.8358	37.5	Olive green..	99	3.5	.7415	41.0	.7816	55.5	.8838	100.0	17.6	2	12.45	.0

Analyses of crude petroleum

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Muskogee County—Continued.
66	Well	Apr. 4	70	1	Pioneer Oil and Gas Co., Muskogee.	1,2,3	1,000	Muskogee pool, old field.
67	do	do	70	1	Connolly well, P. Connolly, Muskogee.	......	1,000	do
68	do	do	70	1	Reeves well, P. Connolly, Muskogee.	......	1,000	do
								Seminole County.
70	Well	Apr. 6	65	5	Wewoka Realty and Trust Co., Wewoka.	1	1,625	Wewoka pool
								Kiowa County.
71	Well	Apr. 7	65	1	Ricketts lease, Whitewater Oil and Gas Co., Gotebo.	2	365	Gotebo pool
72	Tank	do	65	2	Seney lease, Deering Oil and Gas Co., Gotebo.	2	443	do
								Pawnee County.
73	Tank	Apr. 10	60	5	Prairie Oil and Gas Co., Cleveland station.	......	......	Cleveland pool
74	Well	do	60	1	Laterette lease Test Oil Co., Cleveland.	16	......	Cleveland pool in city limits.
75	do	do	60	1	do	17	......	do
76	do	do	60	1	do	15	......	do
77	do	do	60	1	Ohio and Indiana Oil Co., Cleveland.	8-9	......	do
78	do	do	60	1	Cory lease, F. M. Martin, Cleveland.	1	1,157	Cleveland Pool Jordan Valley Township.
79	do	do	60	1	L. L. Cory lease, J. E. Martin, Cleveland.	1	1,174	do
80	do	do	60	1	Berger lease, Prarie Oil and Gas Co., Independence, Kans.	7	1,800	do
81	do	do	60	1	do	4	1,750	do
82	do	do	60	1	Lowery lease, Louisiana Purchase Oil Co., Cleveland.	2	1,620	do
83	do	do	60	1	do	6	1,600	do
								Osage County.
84	Pipe line	Apr. 11	60	5	Prairie Oil and Gas Co., Bartlesville.	......	......	Bartlesville pool
86	Well	do	65	1	Lease 31, Colliver Consolidated Oil Co., Markham & Ball, Bartlesville.	5	1,487	do
87	do	do	65	1	do	6	1,480	do
88	do	do	65	1	Lot 32, Illuminating Oil Co., Bartlesville.	20	1,500	do
95	do	Apr. 8	70	1	T. 26 N., Skelton-Moore Oil Co., Bartlesville.	14	1,088	Shallow Sand pool
								Washington County.
85	Pipe line	Apr. 11	60	5	Prairie Oil and Gas Co., Bartlesville.	......	......	Bartlesville pool
89	Well	Apr. 12	70	1	T. 27, Williams lease, Stubbs & Lowe, Dewey.	4	1,200	Dewey and north of Dewey.
90	do	Apr. 13	70	1	Berger lease, Woodward & Roll, Dewey.	1	525	do
91	do	do	70	1	McEwen lease, Stubbs & Lowe, Dewey.	5	500	do
92	do	do	70	1	Shaler lease, Bartles Oil Co., Dewey.	7	1,250	Webber pool
93	do	do	70	1	Stubbs & Lowe, Dewey	2	1,200	do
94	do	do	70	1	(R. C. A.) Adams Oil and Gas Co., Washington, D. C.	1	1,300	do

from Oklahoma—Continued.

Physical properties.			Distillation by Engler's method.								Unsaturated hydrocarbons.		Paraffin (per cent).	Asphalt (per cent).
Gravity at 60°F.		Color.	Begins to boil at (°C.).	By volume.										
				To 150° C.		150° to 300° C.		Residuum.		Total (cubic centimeters).	Crude (per cent).	150° to 300° (per cent).		
Specific.	Degrees Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.					
0.8216	40.4	Light olive green.	110	5.5	0.7415	46.0	0.7812	43.7	0.8745	95.2	12.0	4	3.88	0.0
.8279	39.1	.....do.......	115	4.0	.7520	48.0	.7856	48.4	.8750	100.4	11.2	2	2.15	.0
.8328	38.1	.....do.......	140	Trace.	....	46.0	.7810	53.2	.8745	99.2	12.4	2	4.91	.0
.8844	28.3	Black........	128	1.5	....	30.0	.8266	67.3	.9067	98.8	30.0	3	6.28	.90
.8480	35.1	Black	115	3.5	.7399	46.5	.7828	51.5	.9097	101.5	29.6	15	5.56	1.30
.8552	33.7	.....do.......	128	2.0	....	40.0	.7884	56.9	.9186	98.9	57.2	3	5.01	.31
.8485	35.0	Black.......	97	10.0	.7428	37.5	.8074	53.2	.8980	100.7	34.8	5	6.06	.20
.8516	34.4	Dark green..	100	9.5	.7794	35.0	.8166	55.4	.8980	99.9	38.4	3	7.75	.03
.8542	33.9	.....do.......	115	2.5	.7705	40.0	.8060	55.4	.8992	97.9	35.2	2	6.63	.15
.8516	34.4	.....do.......	103	7.0	.7586	36.0	.8124	56.4	.8980	99.4	39.2	2	7.86	.81
.8516	34.4	.....do.......	117	4.5	.7670	39.0	.8060	55.9	.8980	99.4	34.8	2	6.62	.30
.8464	35.4	.....do.......	110	5.0	.7530	44.0	.7992	48.8	.8974	97.8	32.4	3	5.55	.05
.8403	36.6	.....do.......	108	7.5	.7398	44.5	.7882	48.5	.8974	100.5	33.2	5	5.59	1.18
.8383	36.9	.....do	80	10.0	.7200	43.5	.7978	47.4	.9056	100.9	38.8	7	5.42	1.12
.8605	32.7	.....do.......	120	1.0	.7603	41.0	.8030	56.9	.8969	98.9	20.4	12	5.68	.92
8459	35.5	.....do.......	85	15.5	.7452	36.0	.8119	49.4	.9032	100.9	26.4	....	4.38	.82
.8669	31.5	.....do.......	140	Trace.	....	39.5	.8139	60.7	.9038	100.2	25.2	4	7.26	.63
.8584	33.1	Dark green..	130	3.0	.7625	39.0	.8116	58.7	.8980	100.7	25.2	2	5.27	.18
.8521	34.3	Black.......	115	3.0	....	43.5	.7818	54.0	.8992	100.5	20.4	9	2.73	1.00
.8505	34.6	.....do.......	105	3.5	.7499	42.0	.7808	51.5	.9044	97.0	30.8	12	2.61	1.34
.8547	33.8	Dark green..	113	3.5	.7574	44.0	.7868	52.4	.9009	99.9	21.0	0	7.90	1.12
.8398	36.7	Black.......	76	11.5	.7101	35.0	.7869	51.9	.9050	98.4	21.2	8	......	1.26
.8521	34.3	Dark green..	103	8.0	.7378	37.0	.8090	54.5	.9038	99.5	24.4	4	3.75	.23
.8605	32.7	.....do.......	103	3.0	....	42.0	.8008	55.7	.9103	100.7	18.8	1	6.07	.47
.8772	29.6	Black.......	128	1.0	.8549	32.0	.7972	63.3	.9024	96.3	38.0	2	3.50	1.43
.8605	32.7	.....do.......	80	9.5	.7299	28.0	.7968	58.5	.9241	97.0	34.8	....	3.68	1.26
.8368	37.3	Dark green..	70	13.0	.7214	32.0	.8008	51.9	.9067	97.9	20.8	4	3.01	.94
.8485	35.0	.....do.......	98	6.0	.7339	40.0	.7928	53.9	.9079	99.9	20.5	11	6.81	.99
.8547	33.8	.....do.......	95	7.5	.7559	39.0	.8128	53.1	.8906	99.6	30.8	14	2.26	.85

Analyses of crude petroleum

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Rogers County.
96	Well..........	Apr. 14	60	1	T. 24, R. 17, Horace M. Adams, Chelsea.	12	400	Alluwe pool.......
97	.....do.........	...do....	60	1	.....do.....................	11	400	.....do........ ..
98	.....do.........	...do....	60	1	Sec. 16, T. 24, R. 16, Steuben lease, H. M. Adams, Chelsea.	38	500	Chelsea pool......
99	.....do.........	...do....	60	1	Sec. 14, T. 24, R. 16, Bennett lease, H. M. Adams, Chelsea.	1	498	.....do...........
								Nowata County.
100	Well.........	Apr. 14	60	1	Sec. 35, T. 27, R. 16, Susan Connor lease, New York and Pennsylvania Oil Co., Nowata.	1	735	Childers pool......
101	.....do.........	Apr. 15	65	1	Sec. 8, T. 26, R. 16, Jane Claggett lease, F. D. Bailey, Nowata.	3	750	.....do...........
102	.....do.........	...do....	70	1	Sec. 31, T. 27, R. 16, Wolf lease, Davis & Berrian, Nowata.	1	812	Delaware pool....
103	.....do.........	...do....	70	1	Sec. 33, T. 27, R. 16, Edgar Bean lease, Van Vleck & Graham Oil Co., Nowata.	4	830	.....do.........
105	Pipe-line tank	...do....	75	5	Prairie Oil and Gas Co., Station 40, Nowata.	......	......	Delaware and Childers pools.
								Nowata and Rogers counties.
104	Pipe line.....	Apr. 15	75	5	Prairie Oil and Gas Co., Station 38, Nowata.	......	......	Shallow Sand pool.

Analyses of crude

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Montgomery County.
106	Well..........	Apr. 16	60	1	Gilroy lease, Brown Brokerage Co., Coffeyville.	1-15	600	Coffeyville pool...
107	Settling tank..	...do.....	60	2	M. Davis lease, Dunkley & Odell, Coffeyville.	1-40	625	.....do............
113	Well..........	Apr. 18	70	1	J. Hall lease, Lynch & McSweeney, Wayside.	1-2	800	Wayside pool.....
114	Settling tank..	...do.....	70	2	.....do.....................	......	......	.....do...........
115	Well..........	...do.....	70	1	G. L. Bank lease, Miller Rider & Co., Independence.	4	1,180	Bolton pool.......
116	Pipe-line tank.	...do.....	70	5	Prairie Oil and Gas Co., station 5, Independence.	......	......	.....do............
								Chautauqua County.
108	Pipe line......	Apr. 17	60	5	Prairie Oil and Gas Co., Peru station, Independence.	......	......	Peru pool.........
109	Well..........	...do.....	60	1	F. G. Hill's lease, Interstate Oil and Gas Co., Peru.	1-2	1,070	.....do............
110	Settling tank..	...do.....	60	1	Hill's lease, Central Pool Oil Co., Peru.	1 12	1,100	.....do............
111	Well..........	...do.....	60	1	Interstate lease, Pittsburg Oil and Gas Co., Peru.	1	1,100	.....do............
112	.....do.........	...do.....	65	....	.....do.....................	6	1,100	....
								Elk County.
117	Well..........	Apr. 18	65	1	Allen County Investment Co., Longton.	2	585	Longton pool.....
118	Settling tank..	...do.....	65	2	....do.....................	......	......	.....do...........

from Oklahoma—Continued.

Physical properties.			Distillation by Engler's method.								Unsaturated hydrocarbons.		Paraffin (per cent).	Asphalt (per cent).
Gravity at 60° F.		Color.	Begins to boil at (°C.).	By volume.										
				To 150° C.		150° to 300° C.		Residuum.		Total (cubic centimeters).	Crude (per cent).	150° to 300° (per cent).		
Specific.	Degrees Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.					
0.8413	36.4	Dark green..	67	10.0	0.7134	33.0	0.7910	54.2	0.9091	97.2	21.2	9	6.14	0.55
.8413	36.4	Greenish blk	65	15.0	.7245	32.0	.7995	50.1	.9168	97.1	23.2	9	2.89	4.01
.8511	34.5	.....do.......	80	13.5	.7148	31.0	.8035	54.8	.9168	99.3	26.0	8	9.10	1.26
.8516	34.4	Dark brown.	97	6.0	.7206	35.0	.7924	54.6	.9272	95.6	26.4	13	4.16	2.19
.8449	35.7	Dark green..	80	14.0	.7415	33.0	.8035	51.2	.9090	98.2	38.4	10	4.51	.75
.8439	35.9	.....do.......	78	11.0	.7270	36.0	.8024	51.1	.9091	98.1	22.0	7.5	4.59	.93
.8493	34.8	Light green..	65	16.5	.7435	35.0	.8195	47.4	.9156	98.9	18.4	8	4.18	1.69
.8424	36.2	Dark green..	81	9.0	.7182	38.5	.7966	51.6	.9138	99.1	12.8	10	8.23	1.74
.8500	34.7	Dark brown.	107	3.0	....	42.0	.7918	49.8	.9103	94.8	24.0	3	4.45	.26
.8537	34.0	Black.......	100	7.0	.7380	39.0	.8034	53.8	.9103	99.8	24.4	3	3.04	.12

petroleum from Kansas.

0.8822	28.7	Dark green..	173	......	....	31.0	0.8082	66.2	0.9138	97.2	22.0	....	5.31	0.17
.8717	30.6	Black.......	100	6.0	0.7289	33.0	.8030	58.3	.9241	97.3	24.4	....		
.8696	31.0	.....do.......	75	9.5	.7100	28.0	.8080	58.9	.9396	97.4	35.6	....	4.66	.61
.8838	28.4	.....do.......	81	5.0	.7315	28.0	.7962	66.0	.9290	99.0	50.0	8		
.8424	36.2	.....do.......	72	14.7	.7273	31.0	.8095	49.2	.9365	94.9	20.0	....	(a)	(a)
.8495	34.8	.....do.......	109	7.0	.7358	36.5	.7982	55.6	.9126	99.1	24.0	6	6.31	.55
.8526	34.2	Black.......	87	7.0	.7244	32.5	.7934	58.7	.9150	98.2	27.6	5	3.81	.35
.8557	33.6	Dark green..	110	7.0	.7310	37.0	.7975	63.2	.9150	97.2	24.8	....	5.79	1.53
.8521	34.3	.....do.......	80	12.0	.7160	30.0	.7945	55.5	.9138	97.5	24.8	3	5.24	.20
.8454	35.6	Black.......	77	11.0	.7218	30.0	.7988	55.3	.9162	96.3	12.4	6	4.54	.42
.8500	34.7	.....do.......	66	13.0	.7177	31.5	.8015	52.5	.9174	97.1	......	3	5.41	.34
.8637	32.1	Black.......	98	12.0	.7202	27.5	.7920	59.3	.9229	98.8	29.6	5	7.19	.89
.8631	32.2	.....do.......	96	6.0	.7360	31.0	.7890	59.6	.9198	96.6	30.8	....	4.30	1.56

[a] With No. 119.

Analyses of crude petroleum

Serial No.	Collected from—	Date of collection.	Temperature of air (°F.).	Quantity collected (gallons).	Location of well.	Number of well.	Depth of well (feet).	Location of pool.
								Wilson County.
119	Well	Apr. 20	70	1	D. Johnson lease, Dolly Johnson Oil and Gas Co., Neodesha.	13	800	Neodesha pool
120	do	do	70	1	T. Johnson lease, Prairie Oil and Gas Co., Neodesha.	3	820	do
121	Settling tank	do	70	5	Dolly Johnson Oil and Gas Co., Neodesha.			do
								Allen County.
122	Settling tank	Apr. 20	75	5	McKinley Crude Oil Co., Humboldt.			Humboldt pool
123	Well	do	75	1	McKinley Crude Oil Co., Humboldt, Logan Township.	11	851	do
124	do	do	75	1	Fussman lease, Logan Township, Frank Fussman, Humboldt.	1	850	do
125	do	do	75	1	do	3	850	do
126	do	Apr. 21	75	1	Hedrich lease, I. N. Knapp, Chanute.	6	700	Chanute pool
127	do	do	75	1	Beach lease, Rex Oil and Gas Co., Chanute.	16	751	do
128	do	do	75	1	do	12	737	do
129	Tank	do	75	5	Kansas Cooperative Refining Co., Chanute.			do
130	Pipe line	do	75	5	Chanute Refining Co., Chanute.			do
133	Well	Apr. 22	65	1	Carroll lease, Eastern Kansas Oil Co., Moran.	4	735	Moran pool
134	do	do	75	1	Smith lease, Eastern Kansas Oil Co., Moran.	2	735	do
136	do	do	70	1	Newton lease, E. F. Holman, Moran.	5	735	do
135	Pipe line	do	75	5	Eastern Kansas Oil Co., Moran.			Moran & Bronson pool.
								Neosho County.
131	Tank	Apr. 21	75	5	Webb lease, Northland Oil and Gas Co., Erie.			Erie pool
132	Well	do	75	1	Barger lease, Buckeye Oil and Gas Co., Erie.	2	520	do
								Miami County.
137	Well	Apr. 23	70	1	C. J. Hafey, Paola	4	360	Paola pool
								Franklin County.
138	Well	Apr. 23	65	1	Springer lease, Hardison & Streeter, Rantoul.	1-4	350	Rantoul pool
139	do	do	70	1	Tullows lease, Hardison & Streeter, Rantoul.	6	350	do
140	Tank	do	70	5	Prairie Oil and Gas Co., Pump station, Rantoul.			do

from Kansas—Continued.

Physical properties.			Distillation by Engler's method.								Unsaturated hydrocarbons.		Paraffin (per cent).	Asphalt (per cent).
Gravity at 60° F.		Color.	Begins to boil at (°C.).	By volume.							Crude (per cent).	150° to 300° (per cent).		
				To 150° C.		150° to 300° C.		Residuum.		Total (cubic centimeters).				
Specific.	Degrees Baumé.			Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.					
0.8373	37.2	Dark green..	80	17.0	0.7172	30.0	0.8005	48.6	0.9079	95.6	18.0	....	3.40 (a)	0.08 (a)
.8368	37.3	Black........	88	16.0	.7158	36.0	.7925	47.7	.9091	99.7	20.0	....		
.8568	33.4	Dark green..	135	1.0	....	40.5	.7994	57.0	.9109	98.5	30.0	3	5.79	.10
.8878	27.7	Dark green..	123	1.0	....	29.0	.8152	68.9	.9247	98.9	32.8	2	3.93	2.33
.8895	27.4	Black........	110	3.0	....	29.0	.8142	67.0	.9284	99.0	23.6	6	1.92	2.68
.8822	28.7	.....do.......	108	5.0	.7460	26.5	.8205	67.4	.9272	98.9	29.6	....	2.10	1.03
.8850	28.2	.....do.......	85	3.5	.7515	27.0	.8160	67.2	.9284	97.7	41.2	8	7.92	.39
.8706	30.8	Dark green..	125	3.0	.7500	37.5	.8029	59.3	.9229	99.8	26.0	1	3.78	.89
.8647	31.9	.....do	109	5.0	.7350	36.0	.7993	57.8	.9223	98.8	24.0	1	4.25	1.23
.8647	31.9	.....do.......	110	6.0	.7375	36.0	.7992	56.6	.9204	98.6	22.4	....	4.71	1.45
.8615	32.5	Black.......	90	7.5	.7156	33.0	.8022	58.7	.9192	99.2	24.0	8	1.45	1.50
.8637	32.1	Dark brown.	113	4.5	.7405	35.0	.7927	57.2	.9174	96.7	24.4	8	4.32	1.15
.8794	29.2	Black.......	95	8.0	.7275	29.0	.8137	61.0	.9358	98.0	19.6	3	1.21	2.63
.8799	29.1	.....do.......	78	10.0	.7105	25.5	.8125	64.8	.9180	100.3	29.2	....	3.48	1.66
.8712	30.7	.....do.......	75	7.5	.7190	25.0	.8135	60.3	.9409	92.8	28.0	....	3.94	2.67
.8589	33.0	.....do.......	106	3.0	.7330	37.0	.7822	59.5	.9192	99.5	27.6	6	4.61	2.32
.8739	30.2	Black	135	1.0	....	34.0	.8000	64.1	.9115	99.1	27.2	7	4.78	3.20
.8658	31.7	.....do.......	110	3.0	....	35.0	.7960	61.8	.9162	99.8	23.6	2	1.22	.88
.8511	34.5	Black	80	10.0	.7202	33.0	.7964	55.8	.9223	98.8	19.6	8	7.44	2.94
.8557	33.6	Black	76	11.5	.7116	29.5	.7950	54.9	.9272	95.9	34.0	....	3.45	2.29
.8750	30.0	.....do.......	136	1.0	....	39.5	.7892	60.1	.9358	100.6	26.0	2	3.98	2.80
.8578	33.2	.....do.......	103	5.5	.7220	33.5	.7850	59.7	.9217	98.7	26.4	6	4.34	1.93

[a] Also No. 115.

THE MADILL OIL POOL, OKLAHOMA.

By J. A. Taff and W. J. Reed.

INTRODUCTION.

LOCATION.

The Madill oil pool, so far as development has proved its extent, is located in the southeastern part of T. 5 S., R. 5 E., Oklahoma, being 1½ miles southeast of the town of Madill and about 12 miles a little west of south of Tishomingo, the former capital of the Chickasaw Nation, Indian Territory. It is within 12 miles of Red River and near the middle of the State from east to west. Madill is at the junction of two lines of the St. Louis and San Francisco Railroad. One is a north-south line through Tulsa and Denison. The other is an east-west road from Ardmore, Okla., to Hope, Ark. (See Pl. I.)

SOURCES OF INFORMATION.

The Madill oil pool lies in the central-southern part of the Tishomingo quadrangle, an area bounded by meridians of longitude 96° 30′ and 97° and parallels of latitude 34° and 34° 30′. The Tishomingo quadrangle was surveyed geologically in 1900 and the Tishomingo folio,[a] a part of the Geologic Atlas of the United States, was published in 1903. The results of the surveys in this region as published in the Tishomingo folio portray almost precisely the geologic conditions proved by the drill in the development of the Madill oil pool.

The presence of oil seeps and the occurrence of bitumen saturating certain sands have from time to time attracted the attention of those interested in oil development in the region of Madill, but it was not until March, 1909, after continued efforts on the part of the MalMillan Oil Company, that the productiveness of an area 1½ miles southeast of Madill was sufficiently proved to induce an influx of operators and cause leasing to be taken up in earnest. On account of this activity a trip of short duration was made to the field about the middle of April, 1909, and that portion of this report pertaining to quality and development of the oil is based in part on the information obtained in the field at that time.

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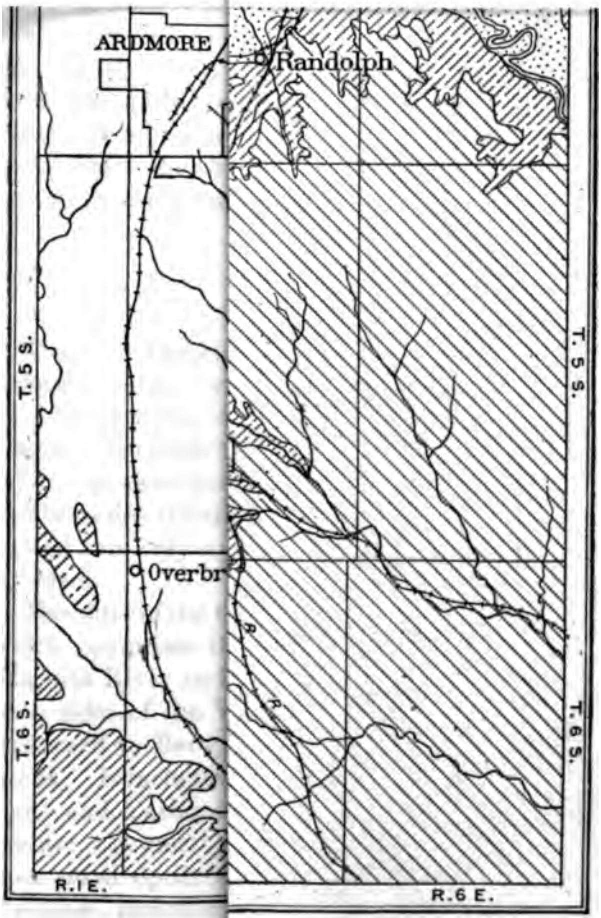
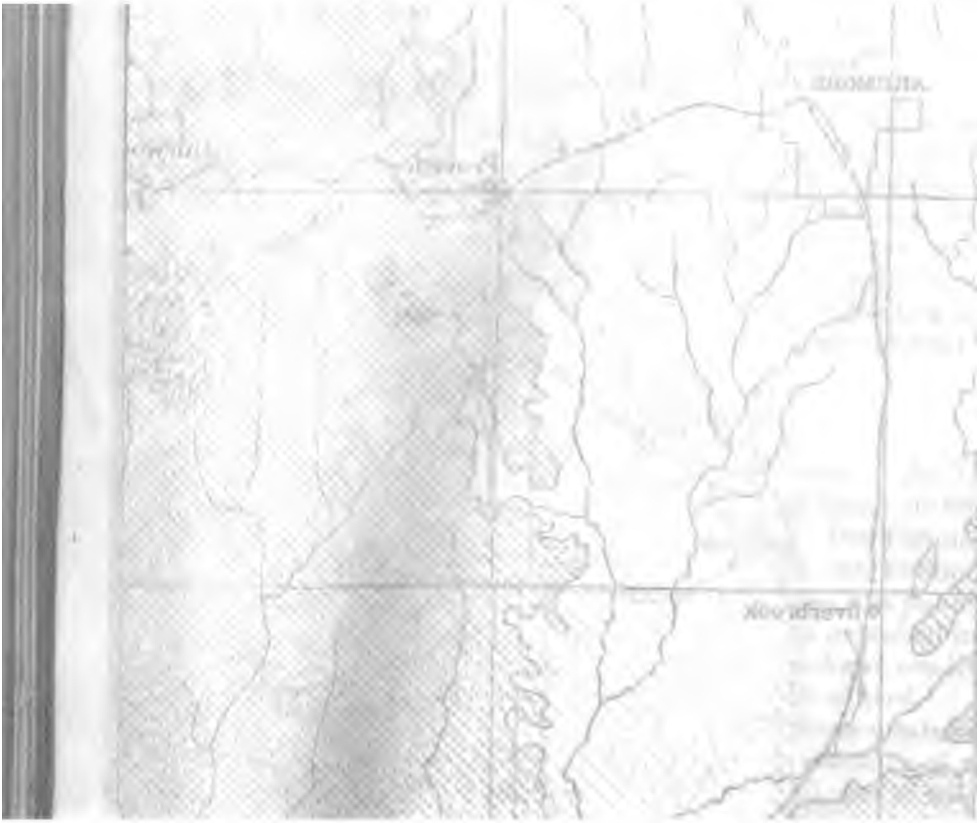
[a] Geol. Atlas U. S., folio 98, U. S. Geol. Survey, 1903.


ARDMORE
Randolph
Overbr
T. 5 S.
T. 5 S.
T. 6 S.
T. 6 S.
R
R
R.1 E.
R.6 E.



CHARACTER OF THE COUNTRY.

The district surrounding Madill is an undulating plain that slopes gently toward the southeast. Washita River, with its broad, shallow valley, lies a few miles to the north and Red River a like distance to the south. The topography has been developed upon comparatively soft limestones, marls, and sands during a long period and under conditions essentially the same as those existing at the present time.

Immediately north of the Washita River valley is the region of the Arbuckle Mountains or Arbuckle uplift. The term "mountains" has been applied, not because high elevations are attained but because of the roughness of the surface and the hardness of the rocks, in distinction to the softer strata and more gentle undulations of the surrounding, slightly lower, and smoother country. The general surface of the Arbuckle uplift is essentially the same as that in the region of Madill; that is, it is an undulating plain, tilted slightly toward the southeast, from which the Cretaceous rocks of the Madill region have been removed in comparatively recent geologic time.

STRATIGRAPHY.

GENERAL OUTLINE.

There are two classes of rocks in the region of Madill, distinguished from each other by great difference in age and by their distinct structure or the attitude of the beds composing the formations. These distinguishing characters have a definite bearing on the occurrence of the oil and deserve more particular mention. The geology of the region has been described in detail in the Tishomingo folio, and will be discussed here only so far as it seems to have a bearing on the petroleum problem.

The older of the two great groups of rocks mentioned is the Paleozoic, which comprises the tilted and folded hard strata that lie north of Washita River and the similarly disturbed softer rocks that lie along both sides of the Washita River valley from the vicinity of Norton westward to Berwyn and thence southward to the vicinity of Overbrook. It includes representatives of the Cambrian, Ordovician, Silurian, and Carboniferous systems, which rest upon pre-Cambrian granite. A small area of the same older Paleozoic rocks is exposed in a small uplift southwest of Overbrook. The second group, the Mesozoic, includes the flat and slightly tilted rocks which lie chiefly south of Washita River and east of Ardmore. The rocks belong to a single system, the Cretaceous. The rock formations are here grouped in a manner suited to their discussion in respect to the presence or absence of petroleum and are so represented on the accompanying map (Pl. XXIII).

TISHOMINGO GRANITE.

The Tishomingo granite is a coarsely crystalline rock which contains a few dikes or intrusions of finely crystalline diabase. It antedates in age the oldest Paleozoic strata in the region, which are probably middle Cambrian. A large area of this granite is exposed north of Washita River and is most probably only a small part of that which is concealed east of Tishomingo by an overlapping formation of sand that has been described as the Trinity sand. The granite extends toward the southeast as a floor beneath the Trinity sand, with a slope of about 40 feet to the mile. It can not be considered in any sense as oil bearing, and any oil that may be found in the overlying Trinity sand has its source elsewhere and has attained its position by migrating laterally in the sand.

OLDER PALEOZOIC ROCKS.

There are six formations of the older Paleozoic rocks that lie in succession, one above another, and that were originally deposited over the granite. They are, in ascending order, the Reagan sandstone (Cambrian); the Arbuckle limestone (Cambro-Ordovician); the Simpson formation and Viola limestone (Ordovician); the Sylvan shale (Ordovician-Silurian); the Hunton limestone (Silurian); and the Woodford chert (Devonian). These formations as now exposed occur south and west of the granite area and are tilted steeply toward the southwest. They are grouped together as shown upon the map. With the exception of three thin formations, one of sandstone, one of shale or clay, and a third of chert, and certain sandy and shaly beds in a fourth formation, the whole section of 7,000 to 8,000 feet of these older Paleozoic rocks is composed of hard dolomites and limestones with some interbedded chert and shale.

The eastern limit of this group of hard rocks is marked by the western boundary of the granite and its southern limit by a definite line of chert hills or ridges produced by the Devonian chert. These chert hills also define the southern boundary of the more elevated Arbuckle Mountainous area.

LATER PALEOZOIC ROCKS.

Overlying the Devonian chert is a great thickness of carboniferous black and blue shale with beds of sandstone. Associated with these rocks are also beds of limestone and limestone conglomerates, and at one locality a bed of coal. Certain sandstone beds in these Carboniferous strata are highly impregnated with semiliquid bitumen, a residue of petroleum. These rock formations have been crumpled into folds and then worn down until the beds which were once deeply buried are now found with their edges projecting at the surface. In the vicinity of Ardmore and Woodford the tarry bitumen exudes from the exposed edges of some of the sandstone beds which have been quarried as bituminous rocks and from which bitumen has been extracted for commercial purposes. Many of the shale beds, especially those near the base of the Carboniferous section, contain disseminated petroleum in places.

CRETACEOUS ROCKS.

The Cretaceous strata lap across the Paleozoic rocks from the granite over the Ordovician and Silurian limestones, the Devonian chert, and the Carboniferous shale, sandstone, etc.

TRINITY SAND.

The lowest and thickest Cretaceous formation is the Trinity sand. It is a compact but unconsolidated, moderately fine sand with a smaller amount of clay and probably local bands or beds of sandy clay. At and near its base the Trinity sand becomes coarser and locally changes to conglomerate. In the vicinity of Ravia and farther east the basal coarse sand of the Trinity is composed largely of granitic material derived from the underlying granite. West of Ravia and probably to the south under cover the basal conglomerate is composed of pebbles and rounded limestone bowlders that had their origin in the hard limestones of the Arbuckle region, immediately to the north. This porous conglomerate and the sand at the base of the Trinity form the receptacle which holds the oil that is being exploited at Madill. The Trinity sand was deposited on a gently undulating or nearly flat surface that had been worn down upon the granite and the various classes of both hard and soft rocks of Paleozoic age above described.

As now situated the edge of the Trinity formation is spread out over a wide extent of country. The drainage of the land is toward the southeast, in the direction of the dip of the Cretaceous rocks, and for this reason large areas of Trinity sand are exposed along the valley of Glasses Creek. Streams south of the railroad between Ardmore and Madill have uncovered a large area of Trinity sand, leaving remnants of the overlying limestone along their divides.

The Trinity sand is approximately 400 feet thick. Because of the slightly uneven floor of the Paleozoic rocks on which it is laid down, the thickness may vary within comparatively short distances, either above or below 400 feet.

GOODLAND LIMESTONE.

In the district shown on the map there are several comparatively thin formations of limestone, clay, and marl that occur in orderly succession, one above another, overlying the Trinity sand. The first of these formations, lying directly on the Trinity, has been described as the Goodland limestone. It is a partly crystalline cream colored to white and moderately hard limestone, and has a thickness of about 25 feet. Its presence is easily recognized because it occurs just above the sand. It is almost continuously exposed along its edge and usually makes barren low bluffs or terraces. Many considerable areas are exposed, and in such areas the Goodland limestone makes a table-land with thin rocky soil. The outcrop of this limestone is of service in that it marks the top of the Trinity sand, near the base of which the oil has been found in the Madill pool. Knowing the approximate thickness of the Trinity sand, the operator can, when the level of his well is referred to the elevation of the Goodland limestone in the vicinity, determine the depth to which he may expect to drill in order to reach the oil horizon.

OTHER CRETACEOUS FORMATIONS.

Resting on the Goodland limestone is a formation of blue clay marl with a few beds of oyster shells. It has been described in the Tishomingo folio as the Kiamichi formation and is about 50 feet thick. This formation makes smooth, rolling black lands.

The Kiamichi marl is succeeded by a formation of limy clay and yellow to white limestone that together have a thickness of about 150 feet. This formation has been described as the Caddo limestone. Some of the limestone beds in this formation are suggestive of the Goodland limestone, but comparison shows that they differ in hardness and that each formation contains fossil shells that distinguish it from the other. Moreover, the limestone beds of this formation are 100 feet or more above the Trinity sand.

Resting on the Caddo limestone is a formation of red and bluish clays with thin beds of shell limestone that weather out to reddish hues. Local beds of sandstone also occur near the top of the formation. This formation has been named the Bokchito and is about 140 feet thick. It occupies but a small area in the district represented by the map and makes the hilly country on the divide south of Little Glasses Creek.

These formations above the Trinity sand are referred to here as an aid to prospective drillers for oil. A knowledge of their occurrence and thickness will assist the operator to determine the depth to the oil sand.

RIVER SAND AND GRAVEL.

Washita River has constructed a wide, flat valley in which it has deposited silt, sand, and gravel. This river alluvium is spread over a width of 1 to 4 miles, in which the river meanders, here and there touching the sides of the valley but not anywhere cutting through to the bottom. Opposite Tishomingo, near the edge of the mapped area, the river deposits are spread over the granite on the north side of the valley and the Trinity sand on the south side. In the vicinity of Norton the river sediment passes upon Carboniferous strata and so continues northwestward beyond the northern boundary of the area mapped. The greatest thickness of the river deposits is not known, but there is reason to believe that it is not more than a very few hundred feet at most.

STRUCTURE.

There are two dominant structural features in the region of Madill that may have a bearing on the occurrence of petroleum. These are the Arbuckle uplift and the Cretaceous monocline. The Arbuckle uplift involves the granite, the older Paleozoic rocks, and the later Paleozoic represented by the Carboniferous formations. Each of these classes of rocks is distinguished on the map. All these formations have been folded up together in a general uplift and the several kinds of rocks are steeply inclined at various angles, in great contrast to the Trinity sand and later Cretaceous rocks, which lie almost flat and incline gently in one direction, thus forming, structurally, a monocline.

ARBUCKLE UPLIFT.

The Tishomingo granite is in the central or axial part of the Arbuckle uplift. This granite mass has doubtless been deformed, but the trend of the folds can not be determined except as indicated by the structure of the older Paleozoic rocks that rest upon it. The Tishomingo granite was not intruded into the sedimentary rocks, but was formed before they were laid down. The older Paleozoic rocks have been warped into a number of folds and are faulted in certain places, but the general inclination of the strata is toward the southwest, away from the granite. Near the granite the rocks dip 10° to 20° SW. Farther to the southwest, near the Carboniferous boundary, the dips are 60° to 80° in the same direction.

The Carboniferous rocks have been thrown into many steep folds that trend in a northwest-southeast direction, with the general uplift of the Arbuckle Mountains. In the vicinity of the Washita River valley west of Norton, on both the north and south sides, the Carboniferous shales and sandstones are tilted steeply toward the southwest. Higher beds in the Carboniferous section occur in many steep folds between Berwyn and Overbrook. The trend of these folded rocks have the same northwest-southeast bearing and the rocks extend beneath the Trinity sand in the direction of Madill.

FAULTS.

Certain faults have developed in the older Paleozoic rocks west of the granite area. These faults or fractures of the strata trend in a northwest-southeast direction, the direction of the Arbuckle uplift. The rocks on the southwest side of each fault indicated on the map have been thrown or have moved downward with respect to the rocks on the opposite or northeast side. The fault that separates the Paleozoic rocks from the granite passes under cover of the Trinity sand 1 mile west of Ravia, bearing in an almost due southeast direction. It is probable that the Carboniferous rocks farther south and also west of Madill may have been faulted in a like manner.

The Carboniferous formations are very similar one to another, being composed chiefly of shales and sandstone, and faults in them are not easily detected. Besides, the Carboniferous rocks in the region of Berwyn and Ardmore have not been surveyed in detail, and faults that extend with the strike of the folds may have escaped recognition. All the disturbances, including the faulting of the Paleozoic rocks, occurred before the Trinity sand was laid down.

CRETACEOUS MONOCLINE.

The structure of the Trinity sand and succeeding formations is extremely simple. These rocks have now probably the same attitude that they had when they were deposited—that is, they lie almost flat and but slightly tilted toward the south. Very slight warpings of the Cretaceous strata have been noted, but no folds have been developed sufficiently to be characterized as anticlines or synclines nor, it is believed, to control or influence the accumulation of oil.

PETROLEUM.

PHYSICAL PROPERTIES.

A fresh sample of crude petroleum was obtained from a well 1½ miles southeast of Madill and shipped to Washington in a gas and oil tight receptacle and analyzed in the laboratory of the United States Geological Survey by David T. Day.

The crude Madill oil is very liquid. Its color in reflected light is dark olive and in transmitted light a dark wine. The specific gravity at 60° F. was 0.7887; the Baumé gravity 47.5°. On distillation by Engler's method 100 cubic centimeters of crude oil began to boil at 65° C. While heating from 65° C. to 150° C. 22 cubic centimeters of gasoline were given off, the specific gravity of which was 0.7118. From 150° C. to 300° C. 38 cubic centimeters of kerosene were given off, with a specific gravity of 0.7788. After heating to this temperature 36.8 cubic centimeters remained as a residuum, of which the specific gravity was 0.8669. In this residuum 7.41 cubic centimeters were determined as paraffin, no trace of asphalt being found. Eight per cent of the crude sample and 1 per cent of the kerosene proved to be made up of unsaturated hydrocarbons.

The gravity of this oil, 47.5° Baumé, is approximately 7° higher than that of the best oil produced at Muskogee, or 13° higher than that of the average Mid-Continent crude oil. On distillation the crude petroleum gave 60 per cent of lighter oil (gasoline and kerosene), about 7 per cent of paraffin, and little or no asphalt. The 6 per cent of lighter oil yielded approximately 22 per cent of gasoline and 30 per cent of kerosene. The average crude oil from the Mid-Continent field, when distilled, produces hardly 50 per cent of lighter oils, with a ratio of about 1 to 4, kerosene predominating.

OCCURRENCE.

The principal oil-bearing rock in this region and the only one which has produced oil in any considerable quantity is at or near the base of the Trinity sand, a little more than 400 feet below the surface at Madill. The oil-bearing rock is a deposit of compact sand and gravel, but the particles and pebbles are not cemented together. Although the oil seems to be almost wholly confined to this horizon, gas has accumulated in other positions in the Trinity sand besides the one in which the oil is found, and this would seem to indicate that oil might be found at similar horizons farther south, where they lie at lower levels and at greater depths from the surface.

The oil sands have been reported to have a thickness of 40 feet, but it appears that the exact thickness of the pay sand may not be over 25 or 30 feet.

DEVELOPMENT.

Up to April 20, 1909, eight wells had been drilled to a depth of more than 400 feet in the vicinity of Madill, and of this number four had been producers, although when the field was visited all were shut in. (See fig. 13.) All the four producers are located on the Jeff Arbuckle farm, in the SW. ¼ sec. 25, T. 5 S., R. 5 E., which is being developed by the Mal-Millan Oil Company, of Madill. A well at the cotton gin on the Madill town site encountered gas at a depth of 180 feet, which, when ignited, produced a large flame that was allowed to burn for a day, after which the gas was cut off in order that the drilling might progress unimpeded.

The well producing the largest volume of oil was completed on March 22, 1909. It was at first reported that the initial production of this well amounted to more than 1,000 barrels, but persons who were present at the well during its early existence and who have had considerable experience in gaging wells flowing into earthen storage tanks place the production at 14 to 16 barrels an hour, or barely 400 barrels a day. The fact should be taken into account, however, in this connection that the wells were drilled with a rotary drill and that the hole in the sand is not more than 3 inches in diameter. As it is not possible to shoot this well, it is not fair to compare its production with that of other wells which have been shot and which have an initial hole with much larger diameter, and as a result give the oil a much greater opportunity for escape. If the Mal-Millan well had been drilled in the ordinary way in which wells are drilled in the Mid-Continent field, that is, with a churn drill of large diameter, it is only a matter of conjecture what the initial production might have been.

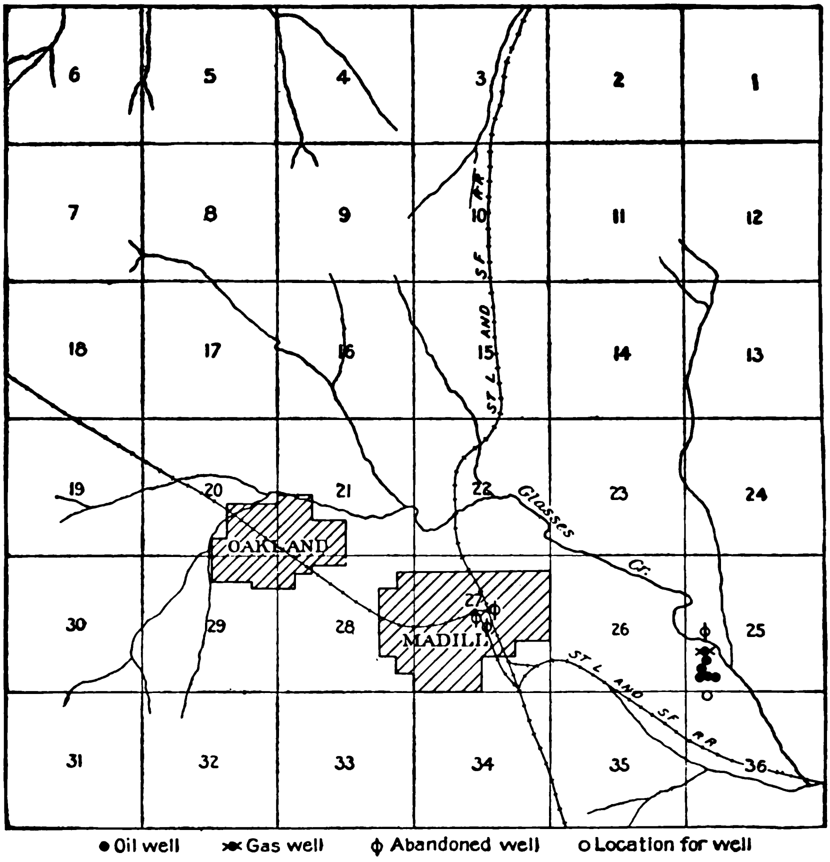


FIGURE 13.—Map of T. 5 S., R. 5 E., showing location of wells drilled in vicinity of Madill, Okla.

One of the producing wells on this farm is developing a considerable quantity of gas, which has been piped to the Arbuckle house and used for domestic purposes. This well also produced some oil, which makes it necessary to open the stop cock at frequent intervals and allow the oil to come to the surface in order that the gas may be given free passage in the casing.

PROBABLE SOURCE OF OIL.

The Trinity sand is known to contain petroleum or bitumen, a residue of crude petroleum, at various localities in southwestern Arkansas, southern Oklahoma, and Texas. At all the localities where this crude petroleum or its residue have been found the Trinity sand is several hundred feet thick. This sand is a beach or shallow-water deposit of siliceous sand with local comparatively thin beds of clay. It contains exceedingly scanty remains of organic life, either vegetable or animal. Here and there thin shell limestone layers occur in the central part of the formation, and at widely separated localities silicified wood has been found, but nowhere is there sufficient evidence of the occurrence of organic matter to warrant the assumption that the oil originated in the formation that contains it.

In southwestern Arkansas and in northern Texas, as well as in southern Oklahoma, thick deposits of Carboniferous rocks that contain oil residues underlie the Trinity sand. Furthermore, the Carboniferous beds are tilted in such a manner that their edges project against the base of the Trinity sand. Any oil in the Carboniferous strata beneath the Trinity would in the course of time be conveyed upward and would either lodge in that sand or find an exit through it to the surface. There seems at present no other reasonable explanation than that the oil of the Madill pool had its source in the underlying Paleozoic strata.

Whether the oil in its present position near the base of the Trinity sand is contiguous to the original oil-bearing strata of the subjacent rocks, or whether it has migrated laterally, may possibly be determined by the drill. Should original oil-bearing strata beneath the Trinity sand be tapped by the drill, the inference is that such oil-bearing rocks would be found to trend in a northwest-southeast direction, with the strike of the rocks in the Arbuckle uplift as exposed in the district to the north and west of Madill.

DEVELOPMENT IN THE BOULDER OIL FIELD, COLORADO.

By CHESTER W. WASHBURNE.

The Boulder oil field was described by N. M. Fenneman in 1905;[a] since that time there has been considerable development of the field which will be briefly mentioned in this paper. The writer spent only one day in the field, January, 7, 1909, under the guidance of Mr. S. F. Rathvon, secretary of the Inland Oil Company.

The most important recent development is the striking on December 29, 1908, of the first gusher or flowing well of the region. This well, No. 13, of the Inland Oil Company, is located in the center of sec. 33, T. 2 N., R. 70 W., on the plunging end of a rather sharp anticline which has been mapped by Fenneman.[b] It had an initial production of about 250 barrels per day, which had decreased to 160 barrels at the time of the writer's visit.

The location of the well at this place was based on the structure of the rocks as shown by the outcrop of the Hygiene sandstone member of the Pierre shale on Fenneman's map. The success of the well corroborates Fenneman's conclusion as to the structure of the locality and makes it seem probable that the productive territory may extend 3 or 4 miles northward along the same anticline toward Lykins Gulch.

Since 1905 the Inland Oil Company has drilled 12 other wells from one-half to 1 mile south of No. 13. Of these wells 8 pumped from 5 to 170 barrels a day, 2 encountered a trace of oil, and 2 were entirely dry. They derive their oil from a sandstone in the Pierre shale 2,000 to 2,500 feet deep. All the productive wells are located on an anticline. Those at the top of the anticline produce gas and light oil which varies in gravity from 42.2° Baumé in well No. 8 to 42.9° Baumé in well No. 3. The wells farther down the limbs of the anticline produce heavier oil mixed with water. The gravity of the oil in these wells ranges from 40.1° Baumé in well No. 7 to 40.7° Baumé in well No. 1. As the oil occurs in sandstone it is probable that this difference in gravity is not due to absorptive fractionation in the rock similar to that observed by David T. Day.[a] The case is similar to those observed by Ralph Arnold in the California oil fields, where the oil associated with water is heavier than that which flows into the wells free from water. A possible explanation is found in polymerization of the oil, by the catalytic action of water, after the manner suggested by Höfer for Trinidad asphalt; or there may be some separation of the oil due to the greater ease with which heavy oil mixes with water. The crude oil is a limpid, yellow, transparent to translucent fluid.

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[a] Geology of the Boulder district, Colorado: Bull U. S. Geol. Survey No. 265, 1905.

[b] Op. cit., Pl. II.

The separation of paraffin from the oil in the wells clogs them rapidly. The difficulty is only partly removed by cleaning the wells. Attempts to warm the wells by steam have failed on account of the high steam pressure required. Some practicable method of warming, therefore, will have to be devised before maximum production can be obtained. The paraffin does not clog the pipe lines, all of which are laid on the surface of the ground, but separates in yellow crystals, which are readily carried in suspension by the oil. In this respect the paraffin is remarkably different from that in the Florence oil, described on page 58.

Besides the wells mentioned above, about six other successful wells have been drilled by other companies since 1905, but the shortness of the writer's visit prevented him from obtaining information concerning them or a small new refinery which they supply.

At the time of the publication of Fenneman's report, the oil of the Boulder field was all shipped to Florence, Colo., where it was refined by the United Oil Company. The selling price of the crude oil was $1.10 per barrel f. o. b. at Boulder. In 1907 the Inland Oil Company completed a modern refinery at Boulder having two stills, each of 400 barrels capacity. At the present time one of the stills charged once a day handles all of the company's oil. The results of the distillation are:

Distillation at refinery of Inland Oil Company, Boulder, Colo.

	Per cent.
Gasolene	20 -22
Water-white oil	38 -40
Gas oil	12½-15
Wax oil	15
Residuum	6- 7
Loss	1- 2

Considerable hydrogen sulphide escapes in the latter part of the distillation. The gasolene has a gravity of 65° to 66° Baumé. The water-white oil, or kerosene, has a gravity of 42.8° to 43.8° Baumé. It has the legal flash test of over 101°, 108°, or 110° F., according to whether it is prepared for the States of Colorado, Wyoming, or Utah, respectively. The heavier "gas oil" is used in enriching illuminating gas. The wax oil consists principally of a high grade of crystalline paraffin with a high melting point, adapted to any of the principal commercial uses of paraffin. The remainder of the wax oil is mostly light lubricating oil. By-products of considerable value are lost on account of the lack of machinery to separate the paraffin wax and the lubricating oils. In the Florence field a similar oil is almost as valuable for these by-products as it is for other constituents. At the present time the wax oil and residuum of the Boulder field are mixed and sold as fuel oil, but on account of the small local demand, the fuel oil accumulates until it has to be burned merely to get rid of it. The fuel oil has been tested on the wagon roads for laying dust, but the tests are said to have been unsatisfactory on account of the light body of the oil.

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[a] Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. U. S. Geol. Survey No. 365, 1908.

The total production of the field was reported to be about 350 barrels a day in April, 1909.

THE FLORENCE OIL FIELD, COLORADO.

By Chester W. Washburne.

INTRODUCTION.

The Florence oil field is located in south-central Colorado. It includes the town of Florence, Fremont County, and extends 4 miles south of that place. It has an east-west extension of 3 miles and a productive area of about 14 square miles.

Reports on the field were made in 1886 by M. C. Ihlseng; [a] in 1888 by J. S. Newberry;[b] in 1891 by G. H. Eldridge;[c] in 1896 by R. C. Hills;[d] from 1901 to 1903 by Arthur Lakes;[e] and in 1904 by N. M. Fenneman,[f] thus covering the history of the field almost from the beginning and preserving data that would otherwise have been lost. The geology of the region has been recently described by N. H. Darton.[g]

The present study was undertaken in the fall of 1908 for the purpose of discovering how the oil occurs. The results of the study will be fully set forth in a later publication and are only partly summarized in this paper.

GENERAL GEOLOGY.

The oil field lies in a synclinal reentrant of the front of the Rocky Mountains, between two en échelon folds made by the Front Range on the northeast and the Wet Mountains on the west. This reentrant is commonly referred to in geologic literature as the "Canon City embayment." (See fig. 14.)

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[a] Report on oil fields of Fremont County: Report of field work and analyses, Colorado School of Mines, 1886, pp. 67-80.

[b] The new oil field of Colorado and its bearing on the question of the genesis of petroleum: Trans. New York Acad. Sci., vol. 8, 1889, pp. 25-28.

[c] The Florence oil field, Colorado: Proc. Am. Inst. Min. Eng., vol. 20, 1892, pp. 442-462, map and cross sections.

[d] The Florence oil field, Fremont County, Colorado; private report for the United Oil Company, 29 pp., maps of wells, topography, and structure.

[e] Prospecting for oil in Colorado: Mines and Minerals, vol. 21, 1901, pp. 481-483, 4 figs.; Petroleum in western North America: Mines and Minerals, vol. 22, 1901, pp. 78-80; The geology of the oil fields of Colorado: Bull. Colorado School of Mines, vol. 1, 1901, pp. 221-226; The geological occurrence of oil in Colorado (abstract): Sci. Am. Suppl., vol. 52, 1901, p. 21505; Oil in Colorado, the geology of the deposits, and the various horizons in which signs of oil have been found: Mines and Minerals, vol. 22, 1902, pp. 256-257; The present oil situation in Colorado, a review of the histories of the several regions, and the discoveries which have been made: Mines and Minerals, vol. 23, 1903, pp. 399-401, 2 figs.

[f] The Florence, Colo., oil field: Bull. U. S. Geol. Survey No. 260, 1905, pp. 436-440.

[g] Geology and underground waters of the Arkansas Valley in eastern Colorado: Prof. Paper U. S. Geol. Survey No. 52, 1906.

STRATIGRAPHY.

The youngest rocks exposed in the Canon City embayment are a coarse conglomerate, 500 feet thick, overlain by a remnant of volcanic tuff. These are regarded as belonging to the Shoshone group. Unconformably beneath the Shoshone strata are 800 feet of fresh-water shales and sandstones containing the coal of the Canon City coal field, and thought to be equivalent to the Laramie formation of the Denver Basin, although the lower part may possibly be of Montana age.

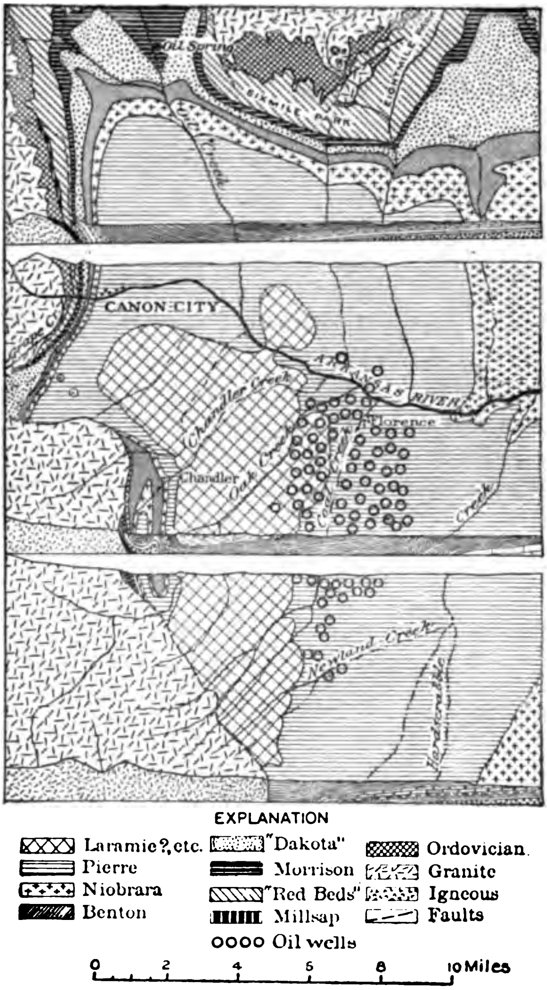

FIGURE 11. Geologic sketch map of the Canon City embayment. After N. H. Darton.

The Montana group of marine strata conformably below these fresh-water beds is subdivided in this report into the Trinidad (?) sandstone and Pierre shale. The former is often referred to as "Fox Hills." The latter is here important because it contains the oil of the Florence field.

The Trinidad (?) sandstone, 100 feet thick, lying at the top of the Pierre shale, is a conspicuous feature of the western part of the field, where it forms an irregular line of low bluffs. It is the uppermost marine stratum, with the exception of the yellow sandstone about 75 feet thick which lies in the coal-bearing formation about 300 feet above the lowest coal bed, and, although not traced through, is believed by Doctor Stanton to be equivalent to the Trinidad sandstone of the Walsenburg, Spanish Peaks, and Elmoro quadrangles.

The upper part of the Pierre shale is sandy, containing many thin beds of sandstone within 300 feet of the top. Below this the shale is nearly a pure clay shale. Marine fossils are locally abundant at various horizons from top to bottom of the shale and fragmental plant remains are common in the upper 700 feet. The total thickness of the Pierre is estimated to be 4,500 feet. Exact measurements are impossible on account of the low dip of the shale and lack of continuous exposure. The Niobrara strata were probably reached at a depth of 2,900 feet in well No. 2b of the Florence Oil and Refining Company. The top of this well is about 1,600 feet below the top of the Pierre. Well No. 349 of the United Oil Company penetrated the shale for 3,750 feet without reaching the underlying Niobrara. The top of this well is about 200 feet below the top of the Pierre.

The Pierre shale is a remarkably uniform body of rock. It is soft and dark gray to greenish black at the surface. Underground the rock is firm, readily fissile along the bedding planes, as shown by the flat platy character of the drillings, and considerable bodies of it are almost white, although dark-gray to bluish-black colors prevail. It is treacherous material to drill through, caving badly into the wells. Numerous hard concretions also interfere with drilling by deflecting the drill and making the holes crooked. The shale consists almost wholly of argillaceous material with no limestone layers or notably calcareous layers except near the base, below the oil-bearing zone, and with no true sandstone except in the upper part, far above the oil zone. Some slightly arenaceous beds contain enough fine sand to feel gritty between the fingers. The grains of quartz in these beds are exceedingly minute, and they are completely embedded in the argillaceous matrix. The rock is too impervious to act as an oil sand in the ordinary way.

Beneath the Pierre shale is the Niobrara group, which in this region has been subdivided into an upper formation, the Apishapa, consisting of light-colored calcareous shale, and a lower formation, the Timpas limestone. Fish scales are abundant in the Apishapa, and both formations everywhere contain much solid bitumen scattered through the pores and smaller joints, but none in the larger fissures. The Apishapa shale is about 450 feet thick and the Timpas limestone about 100 feet thick, including a strong 50-foot limestone at its base, which makes a conspicuous ridge at the foot of the "Dakota" hogback.

The Benton group, underlying the Niobrara, consists of three formations, in descending order the Carlile shale, the Greenhorn limestone, and the Graneros shale. The Carlile shale consists of about 200 feet of very dark gray or black shale, overlain by 8 to 20 feet of coarse-grained calcareous sandstone, charged with very alkaline water. Oil in small quantities is reported from the black shale in a well drilled by A. J. Green 6 miles northeast of Canon City. The Greenhorn limestone consists of about 30 feet of dark-gray calcareous shales and eight to twenty intercalated beds of limestone 4 to 12 inches thick. The Graneros shale includes about 300 feet of dark-gray shale.

The "Dakota" sandstone underlies the Benton group and forms the base of the marine Cretaceous of this region. It consists of two sandstones, each about 100 feet thick, separated by 10 to 15 feet of clay shale. The formation contains artesian water, but in connection with the oil it is interesting principally on account of the solid black bitumen found in it near Canon City.

Beneath the "Dakota" is the Morrison formation, best known in this region for the dinosaur bones which it contains in Garden Park, and most important in the present study because petroleum escapes from it in a few localities. The formation consists of about 400 feet of sandstone and varicolored shales and local thin fresh-water limestones. At the head of the sharp canyon leading out from Garden Park, about 7 miles northeast of Canon City, is an oil spring which has long been known. The oil escapes with water from Pleistocene gravel, locally cemented by bitumen, on the east bank of Oil Creek. It has doubtless entered the gravel from fissures in the underlying Morrison beds. It is a very heavy, black viscous oil, of about 15° Baumé gravity. The quantity now escaping does not exceed 20 gallons a day. One other oil spring is reported on Oil Creek, and one on Hardscrabble Creek about 20 miles farther southeast, both in the Morrison beds. In the same formation a trace of heavy black oil was encountered in the Weaver artesian well about 8 miles southeast of Florence.

Below the Morrison are the following formations: the Fountain formation ("Red Beds"), about 1,000 feet thick; the Millsap limestone (Mississippian), about 200 feet thick; Ordovician strata comprising the Fremont limestone, Harding sandstone, and Manitou limestone, with a combined thickness of about 400 feet; and about 40 feet of upper Cambrian sandstone, which rests upon Archean granite and schist. In the Canon City embayment no signs of oil have been found in these lower formations.

STRUCTURE.

The structure of the Florence oil field has generally been regarded as synclinal, but in the present state of knowledge of the distribution of the oil it would be better to call the field a monocline. The dips in the productive area are low, 3° to 6° W. Just east of the oil field the dips are from 25° to 45° W. West of the known productive territory dips of 2° to 4° prevail for 2½ miles, to the axis of the syncline, where there is a sharp upturning of the beds. The western limb of the syncline is very narrow in comparison with the eastern limb on account of its high dips, 45° E. to 90°, or by overturn, 45° W. to 90°.

The smaller features of the structure, small anticlinal and synclinal cross swells, are too faint to produce changes in dip, but they cause slight irregularities in the general north-south strike. These broad swells have no relation to the distribution of the oil.

Small, sharp anticlines follow the beds of many of the small creeks. These are purely superficial phenomena of recent origin, due probably to the expansion of the rocks when they weather and to the consequent thrusting of the superficial layers into the little gulches. Structures of this type also have no relation to the occurrence of the oil.

Small monoclinal folds passing into faults with a general east-west trend and a throw of less than 50 feet have been noted at several places. These monoclinal folds and faults probably indicate the existence of fissures below them in the oil-bearing zone. It is known definitely that the oil occurs in fissures having the same direction as these monoclinal flexures, and it must therefore be concluded that the presence of east-west fissures and flexures at the surface is a favorable indication of the oil-productive character of the locality. A small monoclinal fold and fault of this type run eastward from a point near the "Blazing Rag" or Bluff Springs mine through the excellent oil territory which lies along the line between Tps. 19 and 20 S. It is quite probable that there are many similar parallel fissures underground in that part of the field.

THE OIL.

MODE OF OCCURRENCE.

GEOLOGIC CONDITIONS.

As previously mentioned, the oil of this field occurs in the Pierre shale, in a zone about 2,500 feet in vertical thickness. It has a stratigraphic range in the shale of more than 3,000 feet, but the productive beds are limited to about 2,400 feet. The upper surface of the productive zone is in places roughly parallel to the dip of the beds, but the upper surface of the zone in which traces and unprofitable amounts of oil and gas are found is in general nearly horizontal, lying from 750 to 1,000 feet deep. The highest traces of oil and gas are reported at about this depth for the entire distance across the field, notwithstanding the fact that the Pierre shale descends 1,600 feet in that distance.

The oil does not follow any bed or series of beds in the shale. As shown by the outcrop, the oil zone does not contain any sandstones or other porous beds capable of acting as reservoirs. The oil lies in joints and fissures. This statement is made without reservation, because the writer believes that it is fully justified by considerations which can not be presented fully in this brief paper. The evidence consists (*a*) of observations on the correspondence in direction of the major joints observable in the rocks at the surface with the alignment of wells which have interfered with each other; (*b*) of the fact that many wells have been drilled within a few feet of each other without encountering oil at the same depth; (*c*) of the fact that gas struck in a shallow well often immediately ruins an adjacent well several hundred feet deeper by tapping the source of pressure; (*d*) of the fact that many wells drain adjacent wells that are very much shallower; (*e*) of the indication of vertical connection between the oil bodies shown by the marked increase in maximum pressure with depth; and (*f*) of the dissimilar pressures in adjacent wells of the same depth.

Corroborative evidence is furnished by the drillers, who report "crevices" in most of the wells, many of which are probably only large concretions in the shale that have been struck on one side, causing deflection of the drill and a crooked hole. In numerous other cases, however, large quantities of water have been poured into a well without moistening the shale sufficiently to enable drilling to proceed, and the conclusion of the drillers that the water has been used up in filling a crevice is probably correct. Less certain are some other observations, such as the reported dropping of the tools as much as 20 feet beyond the distance drilled. This appearance may have resulted from an error in counting depth by the unreliable method of tying strings to the cable. In this connection the following report on the United Oil Company's well No. 402 is interesting: "Bad crevices were found at 2,300 feet, and the bailer was lost in one of these large crevices, but it did not interfere with the drilling, as the crevice was large enough to allow the bailer to be driven into it, without interfering with the work."

It is apparent that a well must strike an open fissure in order to obtain productive oil. It is probable that this fissure is much larger than—in fact, of an entirely different order of magnitude from—the surrounding oil-bearing fissures and pores, which are almost certainly of capillary size. This conclusion is based on the fact that when the oil is struck there is often a sudden rise to heights of 300 to 1,500 feet in wells that immediately afterwards produce only 3 to 5 barrels a day. In one exceptional well the initial rise of oil amounted to 2,500 feet. The high initial rise of oil means that the oil is under high pressure (100 to 800 pounds to the square inch) and that enough of it is in large openings for the dissolved gas to expand quickly and fill the well with oil to the height of the initial rise. As the high rock pressure must decrease slowly in the spaces distant from the well, it must be concluded that tne small flow of oil, lasting in some wells for over twenty years, comes from capillary openings. Conclusive evidence that the general pressure in the rock pores remains high is found in the fact that initial rises of oil amounting to more than 400 feet (pressure over 150 pounds) have been observed in wells drilled within 100 feet of small (2 to 5 barrel) producers that had flowing pressures of less than 5 pounds. The difference in pressure here shown between long-drained fissures and freshly struck fissures can be explained only by supposing that the fissures struck by these wells have no connection except through the exceedingly minute pores and joints of the shale. During the long time, possibly measured by geologic periods, that the oil has been in the rock, equilibrium between the pressure in the fissures and in the pores must have been established. In other words, the pressure in the pores must be of the same order as that indicated by the maximum initial rise of the oil. If the smaller oil-bearing pores have a pressure of 400 to 800 pounds to the square inch, they must be of capillary size, because they offer such enormous resistance to the flow of the oil that it reaches the wells with a flowing pressure of less than 5 pounds to the square inch. It is impossible to escape the conclusion that the oil of the initial rise comes from open fissures and that the oil which flows into the well later is collected from very minute capillary fissures and pores that are tributary to the larger passages. Further support to this idea is furnished by the slight increase in the specific gravity of its oil as a well grows old (see p. 530), because David T. Day[a] has shown that natural fractionation of crude oil is indicative of migration in the capillaries of shale.

INFLUENCE OF WATER.

The concentration of the oil has probably been brought about by water, which is able to shove the oil before it on account of its greater capillary pressure, due to greater surface tension. Partial exploration indicates that the lower part of the syncline is barren of oil, a condition readily accounted for by supposing that the rock pores in that part of the syncline are filled with water. There is some evidence supporting this view. Likewise the east margin of the field lies less than one-fourth of a mile from a line of sharply increasing dip, or monoclinal flexure, along which water could doubtless penetrate the shale more readily than in the gently dipping rocks of the productive territory. Several wells in this belt encountered deep salt water. On the north and south the limits of the field, and hence the relation to water, are not yet known.

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[a] Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. U. S. Geol. Survey No. 365, 1908. See also Proc. Am. Philos. Soc., vol. 36, No. 154, 1897, and Trans. Petroleum Congress (Paris), 1900.

In the vertical distribution of water and oil the relations are much more definite. The oil is hemmed in above by the ground water and below by artesian water in the Timpas limestone and subjacent sandstone of the Carlile. The ground water supersaturates the shale for a distance of 300 to 500 feet from the surface. Above these depths fresh or slightly alkaline water is reported in most of the wells. This water, like the oil 500 feet beneath it, is in open fissures over nearly all the field, except on the west side, where it occurs mostly in the sandy shales and "Fox Hills" sandstone and partly in fissures in the clay shale immediately below these porous beds.

It seems probable that the pores in the shale are saturated or nearly saturated with water down to the upper limit of the traces of oil and gas, which is a roughly horizontal line, 750 to 1,000 feet deep. In parts of the field the vertical sinuosities of the upper limit of traces of oil and gas are similar in position and kind to the sinuosities of the lower limit of reported veins of water. This approach to parallelism between the upper limit of oil and the lower limit of water furnishes an unexpected but convincing argument that water is an important factor in the distribution of oil. The argument is especially strong because both these limits traverse over 1,000 feet of strata in passing from the east to the west side of the productive territory.

Water has rarely been found below 500 feet and only in one or two wells below 1,200 and above 2,500 feet. Wells along the eastern margin of the field commonly strike salt water when they reach the Niobrara formation. In well No. 2b of the Florence Oil and Refining Company salt water encountered in the Niobrara at a depth of 2,910 feet rose to the top of the well. In a few localities evidence has recently been found that some ground water has entered the zone of productive oil through wells that were not tightly plugged when they were abandoned.

The theory that water influences the distribution of oil rests on a deduction concerning the relation of a fluid in capillary pores to the same fluid in supercapillary space that has little observational basis at the present time. The writer believes that water penetrates beyond the lower limits at which it can be detected by flowage into the wells. In this deeper zone the pores of the shale are probably saturated or partly saturated with water, which is held in them by capillary force, leaving no excess to fill the larger fissures. The drillers could observe only the latter, free-flowing, excess water, and probably only in amounts of a barrel or more. It is the invisible capillary water that compresses the oil and tends to drive it through the rock. This invisible, pore-filling water is thought to extend downward through a zone about 500 feet thick which is roughly parallel to the lower limit of the observed ground water. The zone is exceptionally thick where fissures are exceptionally strong or cut through unusual distances. In some places it may touch a similar zone that lies below all the oil horizons and, by crowding the oil aside, make the locality unproductive.

The fissures in the Timpas limestone and the pores in the coarse sandstone at the base of the limestone are filled with water under high pressure, as mentioned above. A score or more of wells in this region, drilled mostly to reach the "Dakota" artesian horizon, have demonstrated that the limestone and sandstone are charged with very salty water. Several deep oil wells in the eastern part of the field have encountered salt water in light-colored shale, presumably the Apishapa shale, above the Timpas limestone. A notable instance is well No. 2b of the Florence Oil and Refining Company, mentioned above. The water in the Apishapa is probably for the most part in open joints and fissures, although the drillers report that in the well just mentioned the water came from "thin black sandstone."

Above the stratigraphic zone of water described in the last paragraph there is probably a thick zone in which water fills the pores of the Pierre shale but not the open fissures. This corresponds with the zone above the oil described on page 524. It hems in the oil below just as the homologous upper zone seals the oil above.

Eldridge[a] thought that the nearly horizontal upper limit of the oil might be due to approximately uniform evaporation. However, it seems impossible for evaporation to be effective through about 1,000 feet of fine shale, the upper 300 to 500 feet of which is known to be full of water. Moreover, evaporation should leave abundant tarry residues, which have not been found. The few traces of unusually heavy oil reported were near the lower as well as the upper limits of oil, two positions where it is thought that the oil comes into contact with water. Polymerization, due to the catalytic action of water, is a possible explanation of these heavy oils, or in migration of the oil driven by water the more viscous heavy oils may have lagged behind, becoming concentrated next to the water. Moreover, it is a fact of common observation that the heavier oils mix readily with water, especially in the presence of suspended clay. Ralph Arnold reports that in the California oil fields the oil which is associated with water in the sands is heavier than the oil from adjacent dry parts of the same sands. In the preceding paper on the Boulder oil field (pp. 514–515) a similar condition is described. It is evident, therefore, that the occurrence of heavier oil above and below the productive zone at Florence may be due to the influence of water.

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[a] Eldridge, G. H., Florence oil field, Colorado: Proc. Am. Inst. Min. Eng., vol. 20, 1892, p. 16.

METHODS OF LOCATING WELLS.

It will be observed on examining the well map (Pl. XXIV) that the symbols indicating producing wells are grouped together in certain localities. These localities are also characterized by a large number of wells that have produced over a million gallons. It is evident that drilling success has been much greater in such areas than in the surrounding areas, where, as the map indicates, only traces of oil and gas and dry wells have been struck. Obviously it will be advantageous to locate new wells on the margins of these favorable areas and in the larger undrilled parts of these areas. This method of locating wells, by following close to the location of previous successful wells, was recommended by R. C. Hills in his report to the United Oil Company.

Less certain is an untried method which the writer has devised that is based on the apparent underground distribution of oil. By drawing cross sections of the oil field it has been found that in certain localities the upper limit of productive oil rises considerably above its general level. These areas where the upper limit of productive oil is high have produced the greater part of the oil, and drilling success within them has been much greater than in the surrounding areas, where the upper limit of productive oil is low. The oil is evidently concentrated in the parts of the rock where it approaches nearest to the surface.

The proposed method of locating wells consists of outlining the parts of the field where the upper limit of productive oil is relatively high and of selecting the undrilled parts of these areas for new wells. In the final report on this field about twenty cross sections of the field will be printed in order to show the changes of position of the upper limit of productive oil. In order that these cross sections may be as accurate as possible, it is hoped that the few independent oil companies who have not furnished records of their wells will endeavor to find these records and send them to the Geological Survey.

On account of the small size of fissures and their probable lack of vertical continuity it seems hardly possible to strike a fissure underground which has been observed at the surface. The location of fissures and small faults should therefore not be considered in deciding the location of wells. Nor should any consideration be given to small anticlines or to the broad anticlinal cross folds, because these have no relation to the distribution of oil.

The spacing of wells is an important matter about which very little information can be given. On account of the fortuitous nature of the direction, length, and intercommunication of fissures it is not possible to make an absolutely safe rule determining the distance between wells. In most of the proved instances of one well draining another the distance between them has been less than 400 feet; but in two probable cases of interference of wells the distance was nearly 1,000 feet. Against these observations should be placed about one hundred others in which wells less than 25 feet apart have not affected one another. Interference between wells that are closely spaced in a north-south direction has not yet been proved, and numerous instances of the lack of such interference might be mentioned. In view of the impervious nature of the shale and the preponderant influence of east-west fissures, it seems safe to locate wells less than 100 feet apart in any approximately north-south direction, ranging between N. 50° E. and N. 60° W. Wells should not be located within 400 feet nearly east or west of big active producers, because of the danger of injury to the latter.

EXTENSIONS OF THE FIELD.

The eastern limit of the field appears to be a north-south line of steep dips that runs through secs. 10, 15, 22, 27, and 34, T. 19 S., R. 69 W. In T. 20 S., R. 69 W., this line of steeper dips takes a west-southwest course toward the south quarter corner of sec. 32. Water penetrating down along the more steeply dipping beds and through fissures along the line of sharp flexure is believed to determine the eastern limit.

South of the field, in the west half of T. 20 S., R. 69 W., the geologic conditions that are capable of surface observation, such as stratigraphy and structure, have the same character as in the productive territory. There is therefore no good geologic reason for thinking that the field can not be extended through T. 20 S., but only seven successful wells have yet been drilled in this township south of the northern row of sections. As already stated, there is evidence tending to show that water has been an important factor in determining the present distribution and concentration of oil in the Florence field. The probable effect of water south of the field would be to constrict the oil territory in that direction, owing to the shorter distance between the water-bearing Laramie rocks or the front of the Wet Mountains west of the field and the belt of steeply dipping rocks east of the field. For the same reason the steeper dips of the Pierre shale in T. 21 S. must be regarded as unfavorable.

The northern limit of the field is not well defined. Several good producers have been brought in north of Arkansas River, three of which were in the NW. ¼ sec. 6, T. 19 S., R. 69 W. Mr. Gumaer reports that the old Robinson well, which was drilled in 1884 a mile north of Cyanide, in the NE. ¼ sec. 5, T. 19 S., R. 69 W., struck oil at a depth of 1,220 feet. After producing about 3 barrels a day for twenty days the well was drilled deeper to 1,500 feet, without encountering more oil, and abandoned. A dry well was drilled about the same time by the Colorado Oil Company in sec. 4, about a mile east of the Robinson well. The geologic conditions of the W. ½ sec. 9 and the N. ½ sec. 8 are not unfavorable for the accumulation of oil.

West of sec. 8 the area in the northwest corner of the region shown on the map (Pl. XXIV), included in secs. 36, 1, 12, 6, and 7, must be regarded as unfavorable territory, because of the number of dry wells drilled in it. A marked synclinal axis runs about N. 10° E. from the southwest corner of sec. 6, west of wells Nos. 206 and 207 and east of wells Nos. 211 and 216 of the United Oil Company. The wells were all dry except No. 206, which had a trace of oil at 1,810 feet. No. 207, however, was only 1,850 feet deep. These test wells indicate that the lower part of the syncline is practically barren of oil.

A location in the neighborhood of Brookside, 2 miles farther west, near the southeast corner of sec. 3, T. 19 S., R. 20 W., would have the same position relative to the north side of the synclinal basin that the developed field has to the east side of the basin. A test well in that neighborhood would seem desirable, but it should be remembered that purely geologic considerations, such as that on which this statement is made, have very little value in the Florence field.

The western limit of the productive territory is sinuous and indefinite, but apparently does not approach within one-fourth of a mile of the west line of R. 69 W. In the north-south strip of land lying from one-fourth to one-half mile east of the township line nine out of twenty-one wells, or 43 per cent, produced some oil. This figure corresponds favorably with the success in the central parts of the field. West of this strip of land, which is largely barren itself, no producing wells have been found, and west of the township line not even a trace of oil has been found in any of the eight wells drilled by the United Oil Company to depths of 1,800 to 2,400 feet. It is highly probable that T. 19 S., R. 70 W., is barren, with the possible exception of the neighborhood of Brookside, which remains to be tested.

PRESSURE.

The oil and gas wells in the field have a flowing pressure of about 5 pounds to the square inch. A few gas wells gave pressure readings of 35 to 75 pounds to the square inch, but these are exceptional. The actual pressure within the oil-filled pores of the rock must be far in excess of these figures. It must be sufficient to raise the column of oil 500 to 2,500 feet high. This requires a pressure of 188 to 810 pounds to the square inch. The higher figure is regarded as nearer the truth, because the greater part of the pressure must be used up in forcing the oil through the pores.

A definite relation exists between the height of initial rise of oil in the well and the depth at which the oil is struck. In a general way the deeper the oil the higher can be the initial rise. It is not true that all the deeper wells have high pressure, but the maximum and average pressures in the deeper wells increase with depth.

The pressure is probably maintained at a very low rate of decline by the expansive property of the gas in the rock pores. The reasons why the gas is under pressure are largely theoretical and will be discussed in the final report. It may be said briefly that hydrostatic pressure can not be effective in the Florence field in the same way as in the Boulder and other oil fields; likewise the pressure is not due to the weight of the rock, because the pressure is much too low, and moreover, there is good reason to believe that in this field the shale is self-supporting on the walls of open fissures, except possibly below 3,000 feet. The source of pressure lies possibly in the forces of capillary action of water and oil.

RELATION TO GAS.

In all the pumping wells there is some gas mixed with the oil. The relative amount of gas is unusually low, amounting in a few wells to less than the volume of the oil. Many wells produce more gas than oil, but in most of these the gas comes from a higher horizon than the oil. The exceptions are all old wells. It is practically a rule without exceptions that the amount of gas in the oil increases as a well gets older. The significance of this rule will be discussed in the final report. No water ever follows the exhaustion of the oil.

Only ten wells are being operated for gas alone. Several of the oil wells produce enough gas to run the boilers, and nearly all produce enough gas to illuminate the wells. Practically all of the gas is used for pumping the oil, either by burning it under boilers or by using it in gas engines. The surplus gas from well No. 16 of the Florence Oil and Refining Company and from the adjacent well No. 2 of the Triumph Oil Company supplies half a dozen dwellings in Florence.

Gas is especially abundant above the productive oil zone, and in this part of the rock it is usually associated with streaks of oil. A few small flows of gas have been struck within a few hundred feet of the surface, but they were quickly exhausted, and it is thought that they have no relation to the gas below.

PHYSICAL PROPERTIES.

The Florence oil is a paraffin oil, dark olive-green by reflected light and reddish brown by transmitted light. Very thin films are yellowish brown.

The mean specific gravity of 48 samples from wells producing in December, 1908, is 0.8709 (equivalent to 30.7° Baumé). The highest specific gravity in these wells is 0.8762 (equivalent to 30.1° Baumé), from the Florence Oil and Refining Company's well No. 42, and the lowest 0.8664 (equivalent to 31.6° Baumé), from Philip Griffith's well No. 17. The oil is generally heavier at the north end of the field than at the south end, but in any locality there is much variation within the narrow range of gravity (1.5° Baumé) mentioned above.

Within the productive zone of shale there is no relation between depth and specific gravity, but above this zone traces of heavier oil have been found in the northern part of the field, and below the productive zone some heavy oil (specific gravity 0.9047, or 24.7° Baumé), was found at a depth of 3,660 feet in well No. 349 of the United Oil Company. As mentioned on page 520, there is some heavy black oil (specific gravity 0.965, or 15° Baumé) in the Morrison formation about 2,600 feet stratigraphically below the productive zone.

The oil in the older wells is heavier than that in the younger wells. By plotting the relation of the specific gravity to the age of the well on coordinate paper, and connecting the mean center points on such a diagram, it is found that the specific gravity increases approximately 0.00015 per year. This observation corroborates the conclusion of David T. Day,[a] that shale has the power of retarding the capillary movement of the more viscous elements of crude oil.

The temperature of the oil in the wells varies from 90° to 135° F., increasing with depth at the rate of about 1° F. for every 44 feet. This high gradient is probably due to the low conductivity of the dry shale.

The oil contains practically no sulphur. A small trace of water is found by distillation, but the quantity is too small to be detected by the eye in the tanks or vessels in which the oil has stood even for several weeks. The oil is practically free from water.

A small amount of mud accumulates in many of the wells and necessitates frequent cleaning. In three of the 48 samples of crude oil collected there is a noticeable deposit of very fine white clay, which has settled to the bottom of the bottles during the five months that they have been standing.

Impure, black paraffin begins to separate from the oil within the wells and accumulates on the pump rods. It interferes little, if at all, with the operation of the wells. The buried pipe lines do not become clogged, and have required only one cleaning in ten years. Surface pipe lines could not be operated in cold weather on account of the high viscosity of the oil and the amorphous nature of the paraffin.

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[a] Gilpin, J. E., and Cram, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. U. S. Geol. Survey No. 365, 1908.

TECHNOLOGY.

The oil is pumped directly from the well tanks through buried pipe lines to tanks at the refineries. The United Oil Company's wells in the southern part of the field pump their oil to a relay station, where larger pumps move it on to the refineries.

There are two refineries, of which the larger, having four stills, each of 600 barrels' capacity, belongs to the United Oil Company; and the smaller, having six stills, each of about 150 barrels' capacity (estimated), belongs to the Florence Oil and Refining Company. At the latter plant the only products recovered are gasoline, kerosene, and gas oil, the residue being sold as fuel oil. Besides these products "Mineral Seal" or signal oil, paraffin wax, and many varieties of lubricating oil are made by the plant of the United Oil Company. All products of the field except paraffin wax are marketed through the Continental Oil Company. All the wax is purchased by the Dupont Powder Company and used in the manufacture of dynamite. The gas oil is used by the Denver Gas and Electric Company in enriching illuminating gas and by the plants at Denver, Salt Lake, and Ogden which make the Pintsch gas familiar to railway travelers.

The results of distillation in the United Oil Company's refinery are:

Distillation at refinery of United Oil Company, Florence, Colo.

	Per cent.
Naphtha, gravity 65° B	4. 15
Water-white oil, gravity 45° B	30. 45
"Mineral Seal" oil, gravity 36.5° B	2. 5
Gas distillate	22. 9
Wax distillate, gravity 29.2° B	40. 0

The "Mineral Seal" oil is more familiar as "signal oil," the name under which it is marketed by the Signal Oil Company, by which the product is handled. The wax distillate yields 10 per cent of paraffin wax, equivalent to about 4 per cent of the crude oil, and 90 per cent of pressed oil. The pressed oil yields 35 per cent of engine oils and 65 per cent of light neutral oils. The latter two groups of oils are altered by filtration and mixing to make different varieties of lubricating oils ranging from light machine oils to heavy black lubricants for car axles. No axle grease or vaseline is being made at the present time.

For comparison with the oils of other regions, the following standard analysis is inserted. This analysis was made under the direction of David T. Day, in the laboratory of the Geological Survey, on a sample of oil from well No. 385 of the United Oil Company. The sample was not fresh at the time of the analysis and hence may be too low in gasoline. The gravity was 30.0° Baumé.

Analysis of oil from company's well No. 385, Florence, Colo.

Gasoline	1.5
Burning oil, specific gravity 0.7988	27.0
Residuum, specific gravity 0.9079	70.2
Paraffin	9.23

HISTORY OF PRODUCTION.

The production of oil began in 1862, when a small still was operated by A. M. Cassedy at an oil spring on Oil or Fourmile Creek, 8 miles northeast of Florence. Most of the oil was obtained from shallow wells 20 to 50 feet deep, in the gravel on the east bank of the creek. The refined product sold in the local markets for $2 to $6 a gallon.

Encouraged by this occurrence of oil in the foothills, Mr. Cassedy induced Isaac Canfield to help him drill a deep well out in the valley. A point about 12 miles south-southeast of the oil spring was selected, near the present town of Coal Creek. In 1876 oil was struck in this well at a depth of 1,187 feet. In the next twelve years about twenty other wells were sunk by B. G. Peabody, A. M. Cassedy, James A. McCandless, J. Wallace, and other men, who organized companies known as the Arkansas Valley Oil and Land Company, the Land Investment Coal and Iron Company, the Colorado Oil Company, and the Canon City Oil Company. These companies obtained many successful wells and started the production of oil on a commercial scale. There are no reliable data of the production of oil until 1887, when the Florence Oil Company (later incorporated as the Florence Oil and Refining Company) was organized and the other companies were amalgamated in the United Oil Company, which has since remained the principal producer of oil in the Rocky Mountain region.

The annual production of the field in the last fifteen years is very uniform in comparison with that of most oil fields of limited area. It has not varied far from 400,000 barrels a year, except in years when the number of wells drilled was greatly increased or decreased. As the drilling success seems to be nearly as good in recent years as in the past, it is practically certain that the decline in production in 1906 and 1907 was due to the small number of wells (10) drilled by the United Oil Company in the two preceding years (1905–6) and to the fact that the independent companies stopped drilling at that time.

The following table of annual production of the field is probably reliable within 15,000 barrels a year since 1893, and within 25,000 barrels a year previous to 1893. The production of several of the independent companies between 1892 and 1900 has been estimated and included in the totals.

Annual production of crude oil of the Florence oil field.

[Barrels.]

1862–1886	(?) 350,000
1887	154,769
1888	180,422
1889	262,203
1890	249,329
1891	309,950
1892	379,148
1893	487,322
1894	429,381
1895	464,004
1896	447,112
1897	401,175
1898	469,133
1899	413,969
1900	383,550
1901	438,082
1902	404,208
1903	452,398
1904	494,716
1905	402,486
1906	319,532
1907	300,230
1908	327,199
	8,510,318

DRILLING SUCCESS.

As in all other oil fields, the success of drilling declines as the field grows older. In the period of the drilling of the first wells, 1878 to 1891, about 65 per cent of the wells struck oil in quantities sufficient to warrant the pumping of the wells. Since 1891 only 40 per cent of the wells have been successful. The following table shows in detail the percentage of wells of the United Oil Company which struck pumping oil between 1887 and 1908:

Annual percentage of successful wells of United Oil Company in the Florence oil field.

1887–88 [a]	72
1889	63
1890	50
1891	75
1892	43
1893	40
1894	11
1895	48
1896	55
1897	41
1898	40
1899	26
1900	42
1901	50
1902	43
1903	40
1904	41
1905–6 [b]	55
1907	37
1908	41

The decline of drilling success in the field since 1890 has been remarkably small. This is best shown by the dotted line on figure 15, which represents the average number of gallons obtained by the United Oil Company for each well drilled in each year. It will be noted on examining this diagram that the drilling success from 1901 to 1908, inclusive, was much better than the success in the earlier period from 1896 to 1900. These figures are especially significant because the company has indulged in very little "wildcatting" outside of proved territory. The low production of the years 1905, 1906, and 1907 is clearly due to the small number of wells drilled in 1905 and 1906. On account of the small number of wells drilled in 1905 the erratic figure obtained for gallons per well drilled in that year has not been platted. This diagram must be regarded as very encouraging, because it indicates such unusual uniformity in drilling success for the last thirteen years. Although the field clearly passed its prime long ago, its exhaustion in the near future is not to be expected.

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[a] Only 14 wells were drilled in the two years 1887 and 1888.

[b] Only 10 wells were drilled in the two years 1905 and 1906.

With the continued cooperation of those having information about the wells, the geologic study briefly summarized in this paper can be made complete, giving better knowledge of the way the oil lies in the rocks. It is hoped that this knowledge will lessen the chances of drilling dry holes and thereby reduce drilling expenses and prolong the life of the field.

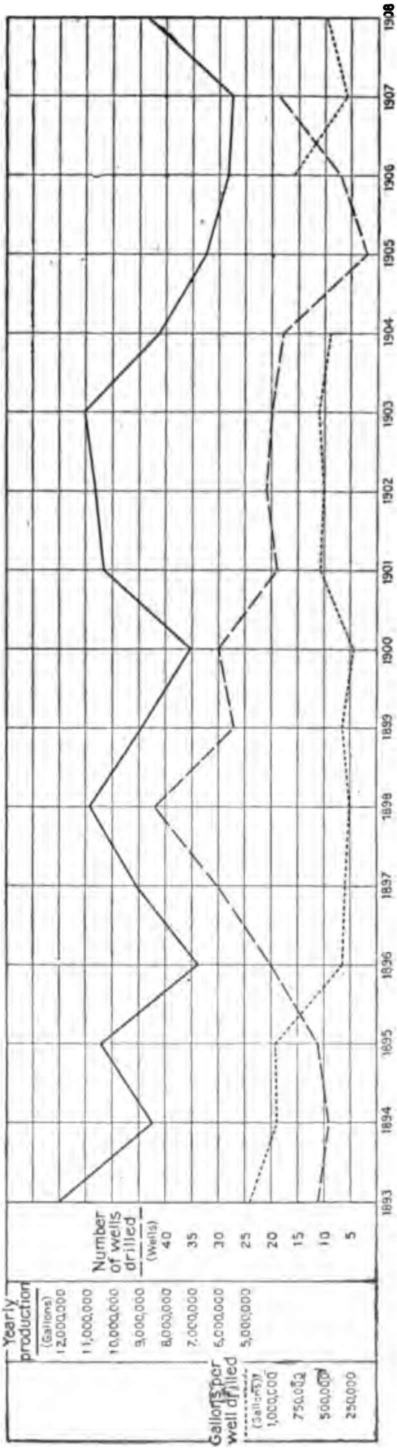

FIGURE 15.—Diagram showing drilling success of United Oil Company in Florence oil field, Colorado, 1887-1908.

EXPLANATION OF WELL MAP.

The map (Pl. XXIV) shows the location and character of about 700 wells. It is very imperfect for the wells of the Florence Oil and Refining Company on account of the poor records kept by that company. The same remark applies to the earlier wells of the Rocky Mountain Oil Company and to many wells of the smaller companies. For publication on the final map the writer will be grateful for any corrections which can be made by those having knowledge of the wells.

The only symbol on the map requiring explanation is the triangle used for large producers. In the case of abandoned wells this triangle designates wells that have produced over a million gallons. In the case of active wells the triangle with points designates either wells that have produced over a million gallons or wells with a very large monthly production and a low rate of decline, indicating that they will probably produce over a million gallons. The symbol is used not to show the present character of a well but rather to show the oil-bearing character of the locality.

On the map, well numbers from 1 to 407 are assigned to corresponding wells of the United Oil Company, numbers 501 to 611 are assigned consecutively to wells 1 to 111 of the Florence Oil and Refining Company with the exception of a few wells whose numbers are unknown, and numbers 701 to 752 correspond to wells 1 to 52, respectively, of the Rocky Mountain Oil Company. Numbers omitted are reserved for unlocated wells about which no information has yet been received. The numbers are explained by the following table:

Key to well numbers on Plate XXIV.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
1	United Oil Co.	1	NW.-SW.	27	19	69
2	do.	2	NW.-SW.	27	19	69
3	do.	3	NW.-SW.	27	19	69
	do.	4	Not known.			
	do.	5	Do.			
	do.	6	Do.			
7	do.	7	N.W.-SW.	27	19	69
	do.	8	Not known.			
9	do.	9	NW.-SE.	16	19	69
	do.	10	Not known.			
	do.	11	Do.			
	do.	12	Do.			
13	do.	13	NW.-SE.	16	19	69
14	do.	14	SE.-SE.	16	19	69
15	do.	15	NW.-NE.	21	19	69
16	do.	16	SE.-SE.	16	19	69
17	do.	17	NW.-NE.	21	19	69
18	do.	18	NW.-NE.	21	19	69
19	do.	19	SW.-SE.	16	19	69
20	do.	20	NE.-NE.	29	19	69
21	do.	21	SW.-SW.	21	19	69
22	do.	22	NW.-NW.	28	19	69
23	do.	23	SE.-NE.	21	19	69
	do.	24	Not known.			
	do.	25	Do.			
26	do.	26	SW.-SE.	16	19	69
27	do.	27	SW.-NE.	21	19	69
28	do.	28	SW.-SE.	16	19	69
29	do.	29	NE.-SE.	21	19	69
30	do.	30	SW.-SE.	16	19	69
31	do.	31	SW.-SE.	16	19	69
32	do.	32	SW.-SE.	16	19	69
33	do.	33	NW.-SE.	21	19	69
34	do.	34	NE.-SE.	21	19	69
35	do.	35	NW.-SE.	21	19	69
	do.	36	Not known.			
37	do.	37	NW.-SE.	16	19	69
38	do.	38	NW.-SW.	27	19	69
	do.	39	Not known.			
40	do.	40	NW.-SE.	21	19	69
41	do.	41	NW.-NW.	27	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
42	United Oil Co	42	SW.-NE.	21	19	69
43	do.	43	SW.-NE.	21	19	69
44	do.	44	NW.-SW.	22	19	69
45	do.	45	NW.-SW.	22	19	69
46	do.	46	SW.-SE.	16	19	69
47	do.	47	SW.-SE.	16	19	69
48	do.	48	SW.-NE.	21	19	69
49	do.	49	SW.-NE.	21	19	69
50	do.	50	SW.-NE.	21	19	69
51	do.	51	NE.-SE.	20	19	69
52	do.	52	SW.-NW.	21	19	69
53	do.	53	NW.-SW.	21	19	69
54	do.	54	NE.-SE.	20	19	69
55	do.	55	SW.-NW.	21	19	69
56	do.	56	SE.-SE.	20	19	69
57	do.	57	SW.-NW.	21	19	69
58	do.	58	SW.-SE.	20	19	69
59	do.	59	SW.-NW.	28	19	69
60	do.	60	SW.-SW.	20	19	69
61	do.	61	SE.-NE.	29	19	69
62	do.	62	NE.-SE.	29	19	69
63	do.	63	SW.-NE.	29	19	69
64	do.	64	SE.-SE.	20	19	69
65	do.	65	SW.-NW.	28	19	69
	do.	66	Not known.			
67	do.	67	SE.-NE.	20	19	69
68	do.	68	SE.-NW.	21	19	69
69	do.	69	NW.-NW.	21	19	69
70	do.	70	SE.-NE.	20	19	60
71	do.	71	SW.-NE.	20	19	69
72	do.	72	SE.-SE.	17	19	69
73	do.	73	SE.-SE.	17	19	69
74	do.	74	NW.-NE.	21	19	69
75	do.	75	SW.-NW.	22	19	69
76	do.	76	NW.-SW.	22	19	69
77	do.	77	NE.-NW.	27	19	69
78	do.	78	NE.-NW.	27	19	69
79	do.	79	NW.-SE.	21	19	69
	do.	80	SW.-NE.	29	19	69
81	do.	81	SW.-NE.	29	19	69
82	do.	82	SE.-SW.	21	19	69
83	do.	83	NW. SE.	29	19	69
84	do.	84	NW.-NW.	28	19	69
85	do.	85	NW.-SE.	29	19	69
86	do.	86	SW.-SE.	29	19	69
87	do.	87	SW.-SE.	29	19	69
88	do.	88	NE.-NW.	28	19	69
89	do.	89	NE.-NW.	32	19	69
90	do.	90	NE.-NW.	32	19	69
91	do.	91	SE.-NW.	32	19	69
92	do.	92	SE.-NE.	20	19	69
93	do.	93	NW.-SE.	20	19	69
94	do.	94	SW.-SE.	20	19	69
95	do.	95	NW.-NW.	21	19	69
96	do.	96	SE.-NE.	20	19	69
97	do.	97	NW.-SE.	20	19	69
98	do.	98	NE.-SE.	30	19	69
99	do.	99	NW.-NW.	32	19	69
100	do.	100	SW.-NW.	32	19	69
101	do.	101	SE.-NE.	31	19	69
102	do.	102	NW.-SW.	32	19	69
103	do.	103	NW.-SW.	31	19	69
104	do.	104	NE.-SE.	30	19	69
105	do.	105	SW.-NE.	31	19	69
	do.	106	Not drilled.			
107	do.	107	SW.-NW.	29	19	69
108	do.	108	SW.-NW.	29	19	69
109	do.	109	NW.-SE.	29	19	69
110	do.	110	NW.-NW.	21	19	69
111	do.	111	NW.-NE.	29	19	69
112	do.	112	NW.-SE.	30	19	69
113	do.	113	NW.-NE.	6	20	69
114	do.	114	NW.-NW.	21	19	69
115	do.	115	NW.-NW.	21	19	69
116	do.	116	NW.-NE.	6	20	69
117	do.	117	NW.-NW.	21	19	69
118	do.	118	NE.-NE.	20	19	69
119	do.	119	NE.-SW.	1	20	70

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
120	United Oil Co	120	NW.-SE	30	19	69
121	do	121	SW.-NE	30	19	69
122	do	122	SW.-SE	17	19	69
123	do	123	SW.-SE	17	19	69
124	do	124	SE.-SW	17	19	69
125	do	125	NE.-SE	18	19	69
126	do	126	NE.-SE	18	19	69
127	do	127	NW.-SE	29	19	69
128	do	128	NE.-NW	32	19	69
129	do	129	SE.-SE	18	19	69
130	do	130	SW.-SE	17	19	69
131	do	131	SW.-SE	18	19	69
132	do	132	NE.-NE	19	19	69
133	do	133	NW.-NW	29	19	69
134	do	134	NW.-SE	18	19	69
135	do	135	SE.-SW	17	19	69
136	do	136	NW.-SE	18	19	69
137	do	137	SE.-NE	18	19	69
138	do	138	SE.-SE	18	19	69
139	do	139	SW.-SE	18	19	69
140	do	140	SE.-SE	13	19	69
141	do	141	SE.-NE	13	19	70
142	do	142	NE.-SW	18	19	69
143	do	143	NE.-SE	18	19	69
144	do	144	SE.-NE	18	19	69
145	do	145	SE.-SW	17	19	69
146	do	146	SW.-SE	17	19	69
147	do	147	NE.-SE	18	19	69
148	do	148	SW.-SW	17	19	69
149	do	149	SE.-NE	18	19	69
150	do	150	NE.-SE	18	19	69
151	do	151	SE.-NE	18	19	69
152	do	152	NW.-SE	18	19	69
153	do	153	NE.-SW	18	19	69
154	do	154	NW.-SE	18	19	69
155	do	155	SW.-SE	17	19	69
156	do		Not drilled.			
157	do	157	SW.-SW	17	19	69
158	do	158	SW.-SW	17	19	69
159	do	159	NW.-SE	18	19	69
160	do	160	SE.-SW	17	19	69
161	do	161	SE.-SW	17	19	69
162	do	162	NE.-NE	18	19	69
163	do	163	NE.-SE	13	19	70
164	do	164	SE.-SW	12	19	70
165	do	165	SW.-NE	13	19	70
166	do	166	NE.-NW	18	19	69
167	do	167	NE.-NE	24	19	70
168	do	168	SE.-NE	24	19	70
169	do	169	NE.-SW	18	19	69
170	do	170	NW.-SW	20	19	69
171	do	171	NE.-NW	29	19	69
172	do	172	NW.-NW	20	19	69
173	do	173	NW.-SE	19	19	69
174	do	174	NE.-SE	18	19	69
175	do	175	NE.-SW	20	19	69
176	do	176	SW.-SW	20	19	69
177	do	177	NE.-NE	19	19	69
178	do	178	NW.-SE	18	19	69
179	do	179	NW.-SW	20	19	69
180	do	180	NE.-SW	20	19	69
181	do	181	NW.-SW	20	19	69
182	do	182	NW.-SE	19	19	69
183	do	183	NW.-NW	20	19	69
184	do	184	NW.-SE	18	19	69
185	do	185	NW.-SE	19	19	69
186	do	186	SE.-NE	19	19	69
187	do	187	NW.-NE	30	19	69
188	do	188	NW.-NE	21	19	69
189	do	189	NW.-NE	19	19	69
190	do	190	SE.-SW	8	19	69
191	do	191	NE.-SW	19	19	69
192	do	192	SE.-NE	21	19	69
193	do	193	NE.-NE	21	19	69
194	do	194	SE.-SW	8	19	69
195	do	195	SW.-SW	8	19	69
196	do	196	SW.-NW	20	19	69
197	do	197	NW.-NE	30	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
198	United Oil Co.	198	SE.-SW.	8	19	69
199	do.	199	SW.-SW.	33	19	69
200	do.	200	NE.-SW.	29	19	69
201	do.	201	NW.-SW.	20	19	69
202	do.	202	NW.-NE.	19	19	69
203	do.	203	NE.-NE.	6	20	69
204	do.	204	NW.-NW.	9	19	69
205	do.	205	SE.-SW.	8	19	69
206	do.	206	SE.-NW.	7	19	69
207	do.	207	SE.-NW.	7	19	69
208	do.	208	SW.-NW.	9	19	69
209	do.	209	SE.-NE.	20	19	69
210	do.	210	NE.-SW.	29	19	69
211	do.	211	SW.-SW.	6	19	69
212	do.	212	NW.-SE.	18	19	69
213	do.	213	NE.-NE.	29	19	69
214	do.	214	SW.-NW.	32	19	69
215	do.	215	SE.-SW.	32	19	69
216	do.	216	SE.-SE.	36	18	70
217	do.	217	NW.-SW.	33	19	69
218	do.	218	SE.-SW.	8	19	69
219	do.	219	NW.-SE.	19	19	69
220	do.	220	NE.-NW.	20	19	69
221	do.	221	NW.-NW.	28	19	69
222	do.	222	NE.-SW.	29	19	69
223	do.	223	SW.-SW.	21	19	69
224	do.	224	SW.-SW.	21	19	69
225	do.	225	SW.-SE.	17	19	69
226	do.	226	NW.-SE.	29	19	69
227	do.	227	SE.-NE.	29	19	69
	do.	228	Not known.			
229	do.	229	SW.-SW.	34	19	69
230	do.	230	SE.-NE.	21	19	69
231	do.	231	SW.-SW.	27	19	69
232	do.	232	NW.-SE.	19	19	69
233	do.	233	SE.-NE.	27	19	69
234	do.	234	NE.-SW.	29	19	69
	do.	235	SE.-NW.	3	20	70
236	do.	236	SW.-NW.	34	19	69
237	do.	237	SE.-NE.	28	19	69
238	do.	238	NW.-SW.	34	19	69
239	do.	239	SW.-SW.	34	19	69
240	do.	240	SW.-NE.	27	19	69
	do.	241	Not known.			
242	do.	242	SE.-NW.	27	19	69
	do.	243	Not drilled.			
244	do.	244	SW.-NW.	27	19	69
245	do.	245	NW.-NW.	34	19	69
246	do.	246	NW.-SW.	34	19	69
	do.	247	Not drilled.			
248	do.	248	NW.-NE.	28	19	69
249	do.	249	SW.-SW.	34	19	69
250	do.	250	SE.-SE.	28	19	69
251	do.	251	SW.-SW.	27	19	69
252	do.	252	SW.-SW.	34	19	69
253	do.	253	SW.-SE.	17	19	69
254	do.	254	SW.-SW.	34	19	69
255	do.	255	NE.-SW.	34	19	69
256	do.	256	NE.-SW.	34	19	69
257	do.	257	SW.-SE.	17	19	69
258	do.	258	SE.-SW.	17	19	69
259	do.	259	NW.-SW.	33	19	69
	do.	260	Not drilled.			
	do.	261	Not drilled.			
262	do.	262	NW.-SW.	33	19	69
	do.	263	Not drilled.			
264	do.	264	SE.-SW.	34	19	69
	do.	265	Not drilled.			
	do.	266	Not known.			
267	do.	267	NE.-SW.	19	19	69
	do.	268	Not drilled.			
	do.	269	Do.			
270	do.	270	NE.-SW.	33	19	69
271	do.	271	NW.-NW.	34	19	69
	do.	272	Not drilled.			
273	do.	273	SW.-SW.	34	19	69
	do.	274	Not drilled.			
	do.	275	Not known.			

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
276	United Oil Co.	276	SW.-SW.	33	19	69
	do.	277	Not known.			
	do.	278	Not drilled.			
279	do.	279	NE.-SW.	19	19	69
	do.	280	Not drilled.			
281	do.	281	NE.-SW.	19	19	69
	do.	282	Not known.			
283	do.	283	NE.-NW.	20	19	69
	do.	284	Not drilled.			
285	do.	285	NW.-SW.	33	19	69
286	do.	286	NW.-SW.	33	19	69
287	do.	287	NE.-SW.	19	19	69
	do.	288	Not known.			
289	do.	289	SE.-SW.	19	19	69
	do.	290	Not drilled.			
291	do.	291	SE.-SW.	19	19	69
	do.	292	Not known.			
293	do.	293	NE.-NW.	30	19	69
294	do.	294	SE.-SE.	20	19	69
295	do.	295	NE.-NW.	31	19	69
296	do.	296	NE.-NW.	30	19	69
297	do.	297	SE.-SW.	32	19	69
298	do.	298	NW.-NW.	32	19	69
299	do.	299	NW.-SE.	18	19	69
300	do.	300	SE.-NE.	18	19	69
	do.	301	Not known.			
302	do.	302	NW.-NW.	30	19	69
	do.	303	Not drilled.			
304	do.	304	SE.-SW.	32	19	69
305	do.	305	NE.-NW.	20	19	69
306	do.	306	SW.-NE.	18	19	69
307	do.	307	SW.-SW.	8	19	69
	do.	308	Not drilled.			
309	do.	309	NW.-NW.	28	19	69
310	do.	310	SW.-NW.	32	19	69
	do.	311	Not drilled.			
312	do.	312	NE.-SW.	19	19	69
313	do.	313	NE.-NW.	20	19	69
314	do.	314	NE.-NE.	20	19	69
315	do.	315	NW.-NE.	20	19	69
316	do.	316	SW.-SE.	21	19	69
317	do.	317	SW.-NE.	18	19	69
318	do.	318	SE.-SW.	32	19	69
319	do.	319	NW.-NE.	6	20	69
320	do.	320	SE.-SW.	32	19	69
321	do.	321	NE.-SE.	32	19	69
322	do.	322	NE.-SE.	31	19	69
323	do.	323	SW.-SE.	32	19	69
324	do.	324	SW.-SE.	32	19	69
325	do.	325	SE.-NW.	20	19	69
326	do.	326	NW.-SE.	21	19	69
327	do.	327	SE.-NE.	28	19	69
	do.	328	Not drilled.			
329	do.	329	NE.-NE.	28	19	69
330	do.	330	NE.-NE.	28	19	69
331	do.	331	SW.-SW.	32	19	69
332	do.	332	SW.-SW.	32	19	69
333	do.	333	NE.-SW.	19	19	69
334	do.	334	SW.-NE.	17	19	69
335	do.	335	NW.-NW.	21	19	69
336	do.	336	SW.-SE.	32	19	69
337	do.	337	NW.-SW.	29	19	69
338	do.	338	SE.-SW.	32	19	69
339	do.	339	SE.-SE.	31	19	69
340	do.	340	SE.-SW.	8	19	69
	do.	341	Not drilled.			
	do.	342	Do.			
	do.	343	Do.			
	do.	344	Do.			
	do.	345	Do.			
346	do.	346	NW.-SE.	29	19	69
	do.	347	Not drilled.			
348	do.	348	NE.-NW.	28	19	69
349	do.	349	SE.-NE.	20	19	69
350	do.	350	SE.-NE.	21	19	69
	do.	351	Not known.			
352	do.	352	NE.-SE.	21	19	69
353	do.	353	SW.-NE.	29	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
354	United Oil Co	354	SW.-NE	28	19	69
355	do	355	NW.-NW	33	19	69
356	do	356	SW.-SW	33	19	69
357	do	357	NE.-SW	21	19	69
358	do	358	SW.-NE	20	19	69
359	do	359	SW.-NE	28	19	69
360	do	360	NE.-SE	29	19	69
361	do	361	SW.-NW	32	19	69
362	do	362	NE.-SE	20	19	69
363	do	363	SE.-SW	6	20	69
364	do	364	SW.-NW	20	19	69
365	do	365	SW.-NE	18	19	69
366	do	366	NW.-SW	29	19	69
367	do	367	NW.-SE	19	19	69
368	do	368	NE.-SW	6	20	69
369	do	369	NE.-SE	32	19	69
370	do	370	SW.-NW	21	19	69
371	do	371	NW.-SW	27	19	69
372	do	372	SW.-NW	6	20	69
373	do	373	NW.-SW	29	19	69
374	do	374	NW.-SE	19	19	69
375	do	375	NW.-NE	16	19	69
376	do	376	SE.-NW	6	20	69
377	do	377	SE.-NE	29	19	69
378	do	378	SE.-NW	21	19	69
379	do	379	NE.-SE	21	19	69
380	do	380	SW.-SW	17	19	69
	do	381	Not drilled.			
382	do	382	SE.-SW	21	19	69
383	do	383	NW.-SW	6	20	69
384	do	384	NW.-SW	29	19	69
385	do	385	NE.-NE	21	19	69
386	do	386	NW.-NW	20	19	69
387	do	387	NE.-NE	29	19	69
388	do	388	SW.-SE	31	19	69
389	do	389	SE.-NE	18	19	69
390	do	390	NW.-SE	28	19	69
	do	391	Not drilled.			
392	do	392	SW.-NW	34	19	69
393	do	393	Not drilled.			
394	do	394	SW.-SE	17	19	69
395	do	395	SW.-NW	6	20	69
396	do	396	SW.-NW	20	19	69
397	do	397	SE.-NE	21	19	69
398	do	398	SE.-SE	20	19	69
399	do	399	NW.-NE	28	19	69
400	do	400	NE.-SE	18	19	69
401	do	401	NW.-SW	28	19	69
402	do	402	NE.-NE	21	19	69
403	do	403	NE.-NW	20	19	69
404	do	404	SE.-SW	17	19	69
405	do	405	SE.-SE	20	19	69
406	do	406	SW.-SW	28	19	69
407	do	407	NW.-NW	20	19	69
408	do	408	SW.-NW	20	19	69
426	American Oil Co	1	NW.-SW	32	19	69
427	Arkansas Valley Oil Co	1	SW.-SW	33	19	69
	Blaney Oil, Gas and Refining Co	1	Not located.			
429	do	2	NE.-NW	16	19	69
430	do	3	NE.-NW	16	19	69
	do	4	Not located.			
	do	5	Do.			
	do	6	Do.			
434	do	7	NE.-NW	16	19	69
435	Birmingham Oil Co	1	NE.-SE	32	19	69
436	Isaac Canfield	1	NW.-SW	32	19	69
437	Carbon Oil Co	1	NE.-SE	17	19	69
438	Centennial State Oil and Development Co	1	Not located.			
439	do	2	SE.-NW	16	19	69
440	do	3	Not located.			
441	Central Oil Co	1	NW.-NE	33	19	69
442	do	2	NW.-NE	33	19	69
443	do	3	SE.-SW	26	19	69
444	City Park Oil Co	1	SW.-NE	16	19	69
445	do	2	SW.-NE	16	19	69
446	Columbia Crude Oil Co	1	NE.-NE	5	20	69
447	do	2	NE.-NE	5	20	69
448	do	3	NE.-NE	5	20	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
449	Columbia Crude Oil Co	4	NE.-NE	5	20	69
450	....do	7	SW.-NW	9	20	69
451	Empire Oil Co	1	NE.-SE	30	19	69
452	....do	2	SE.-NW	17	19	69
453	....do	3	SE.-NW	17	19	69
454	Florence Consolidated Oil Co	1	NE.-NW	4	20	69
455	....do	2	NE.-NW	4	20	69
456	....do	3	NE.-NW	4	20	69
457	Unknown		NE.-SW	27	19	69
458	Frazer Oil Co	1	SW.-NW	16	19	69
459	....do	2	SW.-NW	16	19	69
460	....do	3	NW.-SW	16	19	69
461	....do	4	SW.-NW	16	19	69
462	....do	5	NW.-NW	16	19	69
463	Fremont Oil and Gas Co	1	SW.-SE	33	19	69
464	....do	2	SW.-SE	33	19	69
465	....do	3	NW.-SE	33	19	69
466	....do	4	NE.-SE	33	19	69
467	....do	5	NE.-SE	33	19	69
468	....do	6	NE.-SE	33	19	69
469	Unknown		SW.-NE	21	19	69
470	....do		SW.-NE	21	19	69
471	....do		SW.-NE	21	19	69
472	....do		SE.-NE	21	19	69
473	....do		SW.-NE	21	19	69
474	....do		SE.-NW	27	19	69
475	Philip Griffith	1	NW.-NE	5	20	69
476	....do	2	NW.-NE	5	20	69
477	....do	3	NW.-NE	5	20	69
478	....do	4	NW.-NE	5	20	69
479	....do	5	NW.-NE	5	20	69
480	....do	6	SW.-NW	5	20	69
481	....do	7	SW.-NW	5	20	69
482	....do	8	SW.-NW	5	20	69
483	....do	9	SE.-NW	5	20	69
484	....do	10	SE.-NW	5	20	69
485	....do	11	SW.-NE	5	20	69
486	....do	12	NE.-NW	5	20	69
487	....do	13	NE.-NW	5	20	69
488	....do	14	NE.-NW	5	20	69
489	....do	15	NW.-NE	5	20	69
490	....do	16	NW.-NE	5	20	69
491	....do	17	NW.-NE	5	20	69
492	....do	18	NW.-NW	5	20	69
493	....do	19	NW.-NW	5	20	69
494	....do	20	NW.-NW	5	20	69
495	....do	21	NW.-NE	5	20	69
496	....do	22	NE.-NW	5	20	69
497	Max Grosmeyer	1	NW.-NE	4	20	69
498	Hiawatha Oil Co	1	NE.-NE	8	20	69
499	....do	2	SE.-NE	8	20	69
	....do	3	Not located.			
501	Florence Oil and Refining Co	1	SW.-SW	15	19	69
502	....do	2a	NE.-NW	22	19	69
503	....do	3	NE.-NW	22	19	69
504	....do	4	SW.-SW	15	19	69
505	....do	5	NW.-NE	17	19	69
506	....do	6	NW.-NE	17	19	69
507	....do	7	NE.-NW	22	19	69
508	....do	8	NE.-NW	22	19	69
509	....do	(?)	SE.-NE	7	19	69
510	....do	10	NW.-NW	22	19	69
511	....do	(?)	SW.-NW	8	19	69
512	....do	(?)	SW.-NW	8	19	69
513	....do	(?)	SW.-NW	8	19	69
514	....do	(?)	SE.-NW	8	19	69
515	....do	(?)	NE.-SE	8	19	69
516	....do	16	SE.-SW	16	19	69
517	....do	17	SE.-SW	16	19	69
518	....do	18	SE.-SW	16	19	69
519	....do	19	NE.-NW	21	19	69
520	....do	(?)	NW.-SE	8	19	69
521	....do	(?)	SW.-SE	8	19	69
522	....do	(?)	SW.-SE	8	19	69
523	....do	(?)	SE.-SE	8	19	69
524	....do	(?)	SE.-SW	16	19	69
525	....do	(?)	NE.-NE	4	20	69
526	....do	(?)	SW.-NW	3	20	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
527	Florence Oil and Refining Co.	(?)	NW.-NE.	3	20	69
528	do	(?)	NE.-SE.	8	20	69
529	do	(?)	NW.-SW.	15	19	69
530	do	(?)	NW.-NE.	17	19	69
	do	31-36	Not located.			
537	do	37	NE.-SW.	17	19	69
	do	38, 39	Not located.			
540	do	40	SE.-SE.	8	19	69
541	do	41	SE.-SE.	8	19	69
542	do	42	SE.-SE.	8	19	69
543	do	43	NE.-SE.	8	19	69
544	do	44	NE.-SE.	8	19	69
545	do	45	SE.-SE.	8	19	69
	do	46-52	Not located.			
553	do	53	SW.-SE.	8	19	69
554	do	54	SE.-SE.	8	19	69
555	do	55	SE.-SW.	8	19	69
556	do	56	NW.-NW.	3	20	69
557	do	57	NW.-SW.	15	19	69
558	do	58	NW.-NW.	3	20	69
559	do	59	NW.-NW.	3	20	69
	do	60	Not located.			
561	do	61	NE.-NE.	4	20	69
562	do	62	NW.-NW.	3	20	69
563	do	63	NE.-NE.	4	20	69
564	do	64	NE.-NE.	4	20	69
565	do	65	NE.-NE.	4	20	69
566	do	66	NW.-NW.	3	20	69
567	do	67	NW.-NW.	3	20	69
568	do	68	NE.-SE.	16	19	69
569	do	69	SE.-NE.	17	19	69
570	do	70	NE.-SE.	16	19	69
571	do	71	NE.-NE.	17	19	69
	do	72	Not located.			
573	do	73	SE.-NE.	17	19	69
574	do	74	Not located.			
575	do	75	SE.-SE.	16	19	69
576	do	76	NW.-SW.	16	19	69
577	do	77	NW.-SW.	16	19	69
	do	78	Not located.			
579	do	79	SW.-NE.	4	20	69
580	do	80	NE.-NE.	16	20	69
581	do	81	SW.-NE.	4	20	69
	do	82-85	Not located.			
586	do	86	NW.-SE.	4	20	69
	do	87	Not located.			
588	do	88	SE.-NW.	8	19	69
589	do	89	SE.-NE.	8	20	69
590	do	90	NE.-NE.	8	20	69
591	do	91	SE.-NE.	8	20	69
	do	92	Not located.			
593	do	93	SW.-NW.	16	19	69
594	do	94	NW.-NW.	16	19	69
595	do	95	SE.-NW.	8	19	69
596	do	96	SE.-NW.	16	20	69
597	do	97	SE.-NE.	8	20	69
598	do	98	NE.-SE.	8	19	69
599	do	99	SW.-NW.	16	19	69
600	do	100	SW.-NE.	8	19	69
601	do	101	SW.-NW.	16	19	69
602	do	102	SW.-SW.	16	19	69
603	do	103	NE.-NW.	4	20	69
	do	104	Not located.			
605	do	105	SE.-SW.	15	19	69
	do	106	Not located.			
612	do	2b	NE.-NW.	22	19	69
613	do	2c	NW.-NW.	22	19	69
614	do	2d	NE.-NW.	22	19	69
616	N. P. Hill	1	NW.-SW.	20	19	69
617	do	2	SW.-SW.	33	19	69
618	do	3	SW.-SW.	33	19	69
619	Junction Oil Co.	1	SW.-NE.	16	19	69
620	Mr. Kirk		NE.-NE.	5	20	69
621	Keystone Oil Co.	1	NW.-SW.	10	20	69
622	do	2	NW.-SW.	10	20	69
623	do	3	NW.-NW.	4	20	69
	do	4	Not located.			
625	do	5	NW.-NW.	4	20	69

Key to well numbers on Plate XXIV—Continued.

No. on map.	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
626	Keystone Oil Co	6	NW.-NW...	4	20	69
627	.....do	7	NW.-NW...	4	20	69
628	.....do	8	NW.-NW...	4	20	69
629	.....do	9	SW.-NW...	4	20	69
630	Blaney Oil, Gas, and Refining Co		NE.-NW...	16	19	69
631	.....do		NE.-NW...	16	19	69
632	.....do		NE.-NW...	16	19	69
633	Unknown	3	NE.-NW...	16	19	69
634	McComas Oil Co	1	NW.-NE...	29	19	69
635	National Oil Co	1	NW.-SW...	32	19	69
636	.....do	2	SE.-NW....	28	19	69
637	.....do	3	SE.-NW....	28	19	69
638	Oak Creek Oil Co	1	NW.-SE....	18	19	69
639	.....do	2	NE.-NW...	19	19	69
640	Petroleum Oil Co	1	SW.-SE....	18	19	69
641	Unknown		SE.-NW....	17	19	69
642	.....do		SE.-NW....	17	19	69
643	.....do		SE.-SW....	16	19	69
644	.....do		SW.-NE....	21	19	69
645	Reservoir Oil Co	5	NE.-SW....	4	20	69
646	.....do	6	NW.-SE....	4	20	69
647	Sterling Oil Co	1	NW.-SW...	33	19	69
648	Stadacona Oil Co	1	Near Wetmore, Colo.			
649	.....do	2	SW.-SW....	20	19	69
650	.....do	3	SW.-SW....	20	19	69
651	.....do	4	SW.-SW....	20	19	69
652	.....do	5	SW.-SW....	32	19	69
653	Simon Smith	1	NW.-NE...	17	20	69
654	.....do	2	NW.-NE...	17	20	69
655	Triumph Oil Co	1	SE.-SW....	16	19	69
656	.....do	2	SE.-SW....	16	19	69
	.....do	3	Not located.			
658	.....do	4	SE.-NE....	17	19	69
659	.....do	5	SE.-NE....	17	19	69
	.....do	6	Not located.			
661	.....do	7	SW.-NW...	17	19	69
662	.....do	8	NW.-SW...	17	19	69
	.....do	9	Not located.			
664	.....do	10	SW.-SW....	16	19	69
665	.....do	11	NW.-SW....	17	19	69
666	.....do	36	NE.-SW....	17	19	69
667	Unknown		NE.-SE....	28	19	69
668	.....do		NE.-SE....	28	19	69
669	.....do		NW.-SW...	20	19	69
670	Independent Oil Co	1	SW.-NW...	17	20	69
671	Union Oil Mining and Development Co	1	SE.-SW....	29	19	69
672	.....do	2	NW.-NE...	32	19	69
673	.....do	3	SE.-SW....	29	19	69
674	.....do	4	SW.-SE....	32	19	69
675	.....do	5	SE.-SW....	29	19	69
676	Wilkes-Barre-Colorado Oil Co		SW.-NE....	16	20	69
677	West Lebanon Oil Co	1	SW.-NW...	33	19	69
678	.....do	2	NW.-NW...	33	19	69
679	.....do	3	NE.-SW....	32	19	69
680	.....do	4	NE.-SW....	32	19	69
681	Victor Oil Co	1	NE.-SE....	5	20	69
882	.....do	2	NE.-SE....	5	20	69
683	.....do	3	NW.-SW...	4	20	69
684	.....do	4	NE.-SE....	5	20	69
685	.....do	5	NE.-SE....	5	20	69
686	.....do	6	NE.-SE....	5	20	69
687	"Robinson" well		NE.-NE....	5	19	69
688	Unknown		NE.-SW....	17	19	69
689	Mr. Caldwell	1	NW.-NE...	6	20	69
690	Lobach Oil Co		NW.-NW...	16	19	69
691	.....do		SE.-NE....	17	19	69
692	Continental Oil Co	1	SW.-SW....	9	19	69
693	Columbia Crude Oil Co	5	NE.-NE....	5	20	69
694	.....do	6	SE.-NE....	5	20	69
701	Rocky Mountain Oil Co	1	NW.-SE....	28	19	69
702	.....do	2	NW.-SE....	28	19	69
703	.....do	3	NW.-SE....	28	19	69
704	.....do	4	NW.-SE....	28	19	69
705	.....do	5	NW.-SE....	28	19	69
706	.....do	6	NW.-SE....	28	19	69
707	.....do	7	SW.-SE....	28	19	69
708	.....do	8	NW.-SE....	28	19	69
709	.....do	9	SW.-SE....	28	19	69

Key to well numbers on Plate XXIV—Continued.

No. on map	Owner.	Owner's No.	Location.			
			Quarter.	Section.	Township S.	Range W.
710	Rocky Mountain Oil Co	10	NW.-SE	28	19	69
711	.....do	11	NW.-SE	28	19	69
712	.....do	12	SW.-SE	28	19	69
713	.....do	13	NW.-SW	28	19	69
714	.....do	14	NW.-SW	28	19	69
715	.....do	15	NW.-SW	28	19	69
716	.....do	16	NW.-SW	28	19	69
717	.....do	17	NW.-SW	28	19	69
718	.....do	18	NW.-SW	28	19	69
719	.....do	19	SW.-SW	28	19	69
720	.....do	20	SW.-SW	28	19	69
721	.....do	21	SW.-SW	28	19	69
722	.....do	22	SW.-SW	28	19	69
723	.....do	23	SW.-SW	28	19	69
	.....do	24	Not located.			
725	.....do	25	SE.-NE	32	19	69
726	.....do	26	SE.-NE	32	19	69
727	.....do	27	NE.-SE	32	19	69
728	.....do	28	NE.-NE	32	19	69
729?	.....do	29	SE.-NE	32	19	69
730	.....do	30	SE.-SE	32	19	69
731	.....do	31	SE.-SE	32	19	69
732	.....do	32	SW.-SE	32	19	69
733	.....do	33	SW.-SE	32	19	69
734	.....do	34	SE.-NE	32	19	69
735	.....do	35	NE.-NE	32	19	69
736	.....do	36	SW.-SE	28	19	69
737	.....do	....	Not located.			
738	.....do	38	SE.-SE	32	19	69
739	.....do	39	SW.-SE	32	19	69
740	.....do	40	NW.-SE	32	19	69
741	.....do	41	NW.-SE	32	19	69
742	.....do	42	NE.-SE	32	19	69
743	.....do	43	NW.-SE	32	19	69
744	.....do	44	NE.-SE	32	19	69
745	.....do	45	NW.-SE	32	19	69
746	.....do	46	NE.-NW	32	19	69
747	.....do	47	SW.-SE	28	19	69
748	.....do	48	NE.-SE	28	19	69
	.....do	49-51	Not located.			
752	.....do	52	NW.-SE	28	19	69

SURVEY PUBLICATIONS ON PETROLEUM AND NATURAL GAS.

The following list includes the more important papers relative to oil and gas published by the United States Geological Survey or by members of its staff. The United States publications, except those to which a price is affixed, can be obtained free by applying to the Director, U. S. Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Certain of the geologic folios also contain references to oil, gas, and asphaltum.

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